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President's Page

The XIIth General Assembly of the IUGG

The almost unbelievable success of the IGY was abundantly confirmed at the meetings of the International Union of Geodesy and Geophysics at Helsinki this summer. Coming at a time when many IGY observations had been reduced, collated, and interpreted, we can recognize a 'quantum-jump' in our understanding of the interplanetary environment. The work of the International Association of Geomagnetism and Aeronomy, for example, whose meetings at Copenhagen and Helsinki are reported in the following pages, shows remarkable progress toward a coherent picture of heretofore poorly connected phenomena.

The active regions of the Sun are now defined by plages seen from space platforms in the ultraviolet and the x-ray radiations. These correspond closely to the plages seen in calcium emissions. The solar spectrum has been extended by rocket spectrographs right down to the x-ray region, and its line intensity has been photospectromically evaluated. The Lyman-α 1215 A and SiII-520 A lines as well as the 1–100 A soft x-ray radiations emerge as major actors in dissociating, exciting, and ionizing our outer atmosphere, though many other emission lines play vital roles.

Solar chromospheric eruptions provide the sources of disturbance. Smaller eruptions produce noticeable effects, but the great intensity-3 flares, accompanied by Type IV radio disturbances, are the outstanding contributors. From such flares are propagated explosive shock-waves that initiate the Type IV radio noise in synchrontron-type of particle acceleration, and lead to a multiplicity of subsequent events that affect the Earth in many ways.

All solar flares seem to inject dense clouds of low energy particles into space. These clouds appear to be focussed into remarkably well defined streams, and to travel away from the Sun with a velocity of about 2000 km/sec, producing magnetic and ionospheric storms, aurorae, and the like as they intercept the Earth about a day after the flare. But, in addition, the great flares with Type IV radio-noise emission radiate a broad cloud of high energy particles of 100 MEV or more, which reach the Earth as soon as one to four hours after the flare—a day or so ahead of the slower cloud of particles. The arrival of these MEV particles is heralded by a blackout of radio transmission over the polar cap, where the high energy particles can be scattered through the geomagnetic field into the ionosphere. The arrival of these particles with the coincident polar blackout follows the Dellinger fade-out in the ionsophere that is induced by intense x-radiation from the flare. It is conceivable, though not proven, that the great bursts of prompt solar cosmic rays that sometimes follow such flares are merely the upward extensions of the energy range of the MEV particles emitted by flares, and accompanied by Type IV radio noise.

We now learn that the Forbush decreases in cosmic rays, which accompany some but not all magnetic storms, are always initiated by the great flares having Type IV noise, with their resultant blackouts over the polar cap. Thus, the Forbush decrease is associated with solar-flare emission of particles in the MEV range. Quite clearly, Pioneer V data, which detected Forbush cosmic ray decreases far from the Earth, and very recent ground cosmic ray recorders of fast response, which find that such decreases sometimes occur a little *before* the outset of the magnetic storms, demonstrate that the Forbush decreases are of interplanetary character and hence are not geocentric. Therefore, the rather close coincidence of the For-

bush decrease with the geomagnetic storm, about a day after the intense flares, requires an intimate study of the sequence of events before it can be explained fully.

Based on phenomena that originate on the Sun, studies of magnetic storms can now be made under two broad classifications. First, there are the magnetic storms that follow great flares with Type IV noise; these are preceded by streams of high energy particles, in the MEV range, that produce the polar cap blackouts, and whose energies, at times, extend into the cosmic ray range—events that are always accompanied by a Forbush decrease in cosmic rays. Second, there are the magnetic storms that involve only the interception of the Earth by slower particle streams—those that seem to characterize the initiation of all magnetic storms.

The magnetic storm itself seems to be characterized by three phases, though the intensity and duration of each phase may be quite different for successive storms. The first phase is the sudden commencement, manifested by a sharp rise induced by the current system at the front of the particle stream, with its imbedded magnetic field, as it reacts in its first encounter with the Earth's magnetic field. The second is the violent fluctuation of the magnetic field as the particle stream penetrates to the auroral zone, producing strong aurora, and violently distorting the geomagnetic field as intense current systems spread around the polar regions. The third, comes from the injection of particles through a distorted magnetic field into the Van Allen radiation belts, producing equatorial Chapman-Ferraro ring-currents in the Van Allen belts, which last one to four days and decay slowly, accounting for geomagnetic post perturbation. During the July 15, 1959, event this ring-current exceeded one and a half million amperes around the Earth. The vast and complex distortion of the outer regions of the Earth's magnetic field during this succession of events is apparent. Out of these events fall naturally the quantitative explanation of many previously unexplained phenomena. The new and more advanced views offer a real opportunity for more detailed study and classification of magnetic storms in terms of definable phenomena that produce them.

Not all of the low energy streams encounter the Earth; many miss it by millions of miles. But they can be seen clearly as they flow out past the Earth into space, distorting the directional symmetry of primary cosmic ray particles that reach the Earth.

The existence of an interplanetary magnetic field, upon which are superimposed these hydromagnetic plasmas of varying energies, now seems beyond question. Collision of the shockwaves of such plasmas with the Earth's field seems to produce regular elastic oscillations of the geomagnetic field and of the bound, ionized atmosphere within it, as indicated by micropulsations of the geomagnetic field before and during the magnetic storm.

An equally fascinating panorama of our outer atmosphere and exosphere is emerging from the coordinated IGY studies of the ionosphere, exosphere, and auroral and air flow emissions. The composition, density, photochemistry and temperature of the outer atmosphere, with its complex problems of excitation, dissociation, ionization, attachment, recombination, diffusion, and convection, are approaching broad understanding. In the daylight sector, the atmosphere forms an outward bump several hundred kilometers high, and the temperature and density of the bump are noticeably responsive to the variations of solar activity with the accompanying short wave radiations that react noticeably on the atmosphere.

However, with these great steps forward in our knowledge, new questions are posed. Just what is the strength of the interplanetary field? What is its orientation? How do the turbulent plasmas of different energy levels react to deform and penetrate it? What is the influence of the atmospheric bump on the atoms of the exosphere, which must otherwise execute orbits, like satellites, around the Earth? One can now ask a thousand new questions that become significant only in the light of our great advance in knowledge.

Perhaps of greatest importance is the study of interplanetary phenomena and of their reactions on the Earth during sunspot minimum. Fortunately, the IGY occurred at a time when the Sun's activity was the greatest in the history of observation. There is some suspicion that the Sun's activity is increasing steadily in the present epoch. There is also some evidence that, in the present era, this activity may come

primarily from a single very active area on one side of the Sun. With a forthcoming sunspot minimum, the feeling is growing that a "little IGY" should be carried out during the 1964–65 interval to provide detailed comparison with the IGY years and with the forthcoming maximum in the early 1970's. Indeed, the evidence is strong that our external environment is more radically altered at sunspot minimum than we had previously supposed. Consequently, much talk at the IUGG Assembly centered on an "IGY Minimum" program, and the matter has been brought to the attention of the CIG. General agreement was evident that from our new vistas, the questions can be more critically asked, and the experiments more analytically conceived. It was significant that the old refrain "our conclusions require more data to confirm" was heard very little, for the IGY was, for the first time, sufficiently complete. Rather, we heard "this unambiguous conclusion suggests the following experiment." Such change in thinking is a revolution in geophysics. No longer do geophysicists who work with solar-terrestrial relations feel that they are pressing hard against dead ends. Rather, there are more exciting questions to ask than one can find time to answer.

In particular, the wisdom of incorporating the programs for rockets and satellites within the IGY is now abundantly evident. Rockets and satellites have not only made discoveries and critical measurements in their own right, but they have given an integrated meaning to a whole body of disconnected geophysical evidence.

In looking back over the IGY, one cannot but enjoy the overwhelming defeat of the pessimists. "It will cost too much!" "What do you expect can possibly come from it!" "Nations will never cooperate; they will not do their part; they will keep their data secret!" "You will just pile up a lot of useless data!" "Where will you find trained men to do the job?" The overwhelming progress in knowledge, as a consequence of the IGY, is the complete answer. The job is not yet done, for the discoveries suggest new analysis to reveal the secrets that the IGY data still contain. We look to CIG to encourage this process. But, too, we look for international cooperation, within the frameworks of the CIG, the UGGI, the URSI, the IAU, and the ICSU, that will permit those worldwide experiments that can further advance our fascinating and fruitful field of knowledge—geophysics.

LLOYD V. BERKNER, PRESIDENT

Twelfth General Assembly International Union of Geodesy and Geophysics*

Helsinki, Finland, July 25 - August 6, 1960

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*This report was prepared at the request of Principal Delegate, L. V. Berkner, under the direction of the chief delegates to the Associations. Chief Delegates were as follows: *Geodesy*, Charles Pierce; *Seismology and Physics of the Earth's Interior*, L. M. Murphy; *Meteorology and Atmospheric Physics*, T. F. Malone; *Geomagnetism and Aeronomy*, L. R. Alldredge; *Physical Oceanography*, W. H. Munk; *Volcanology*, J. F. Schairer; *Scientific Hydrology*, W. B. Langbein. The Chief Delegates were responsible for the assignment of reporters, and the compilation of their reports on the sessions of the respective Associations. Acknowledgement is made of these services. The General Report was prepared by Executive Secretary Waldo Smith. The Administrative Report was prepared by J. W. Joyce, Chairman of the Committee on International Participation. These reports are based on material prepared by various members of the National Academy of Sciences—American Geophysical Union Delegation to the XIIth General Assembly of the IUGG at Helsinki. The material has been supplemented by unedited drafts of IUGG and Association documents, including resolutions. Inasmuch as the reports have not been reviewed by IUGG officials, it is *not* to be considered an official IUGG account of the meetings.

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Twelfth General Assembly International Union of Geodesy and Geophysics

Helsinki, Finland, July 25 - August 6, 1960

General Report

The Twelfth General Assembly of the International Union of Geodesy and Geophysics was held in the friendly, academic atmosphere of the University of Helsinki, located near the heart of the capital and metropolis of Finland, from July 25 to August 6, 1960. Lloyd V. Berkner, President of the American Geophysical Union, served as Chief Delegate from the United States. The principal delegates to the Associations were: Geodesy, Charles Pierce; Seismology and Physics of the Earth's Interior, Leonard M. Murphy; Meteorology, Thomas F. Malone; Geomagnetism and Aeronomy, Leroy R. Alldredge; Oceanography, Walter H. Munk; Volcanology, J. Frank Schairer; Hydrology, Walter B. Langbein.

A detailed account of the proceedings of each association follows the general and administrative reports.

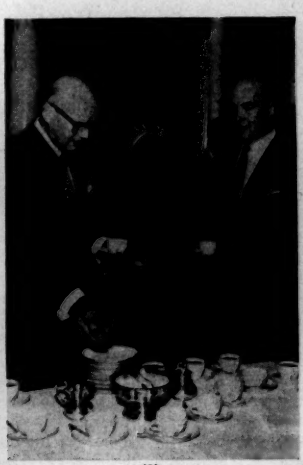
The opening plenary session on Tuesday, July 26, drew the group together for the first time, and several hundred attended in the Exhibition Hall away from the center of the city. This was attended by the President of Finland and Mrs. Kekkonen, by the ambassadors and other diplomatic representatives of various countries, as well as by many of those attending the Twelfth General Assembly. President J. Tuzo Wilson opened the meeting, and introduced Heikki Hosia, the Minister of Education, who welcomed the group to Finland and paid tribute to the work of scientists. Pontus Palmgren, Vice Rector of the University, extended a welcome for the University, and Vice President Heiskanen gave an address of welcome on behalf of the Finnish Committee. Following two numbers by a string quartet, President Wilson expressed thanks for the welcome, and announced that the regular Presidential Address would be presented at an evening meeting. He noted our great losses through death during the last triennium, mentioning especially Beno Gutenberg, Francesco Signore, and I. P. Bardin, and noted the work of the Union during the last triennium, including the great work undertaken and accomplished by the international IGY group. General Secretary Laclavère then presented his report on the activities of the General Secretary during the last triennium.

There were about 2000 registrant scientists, technologists, and their guests who took part in the scientific proceedings of the Union and its seven associations. Of the 61 member countries, 44 sent delegations. In addition, observers were present from eight non-member countries.

The headquarters of the General Assembly was in the building known as The University, a large four-story building occupying a full block, and having in it the festival hall of the University and many classrooms and offices. Besides being headquarters for the General Administration of the Assembly, this building served also for most of the meetings of the Associations of Geodesy, Seismology and Physics of the Earth's Interior, and Oceanography. Diagonally across one of the intersections is the spacious new University building known as the Porthania, which contains spacious student facilities including a dining room, lounging quarters, and many classrooms. The sessions in Meteorology, and Geomagnetism and Aeronomy, and most of the evening sessions were held in this building. About a block away is the spacious Forestry Building, where most of the sessions in Hydrology and Volcanology were held.

A number of joint symposia were held, which attracted much attention, and which many felt were the most important scientific sessions

(1)



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(Figures and names read left to right throughout)

1. J. Tuzo Wilson, President of IUGG; Pentti Kalaja, Co-Secretary of the Finnish Committee on Arrangements; Georges Laclavere, General Secretary of IUGG; and an unidentified person.

2. Urho Kekkonen, President of Finland, and J. Tuzo Wilson, President of IUGG.

3. Three elder statesmen of the IUGG: F. A. Vening-Meinesz (The Netherlands), Walter D. Lambert (USA), J. de Graaff Hunter (Great Britain).

4. Leason H. Adams, Past President of AGU; T. J. Kukkamäki, Secretary of the Finnish National Committee and Co-Secretary of the Finnish Committee on Arrangements; W. A. Heiskanen, Vice President of IUGG and President of the Finnish Committee on Arrangements.

5. Thomas F. Malone, Vice President of AGU and President of the Section of Meteorology; Helmut Landsberg, Past President of the Section of Meteorology; F. W. Reichelderfer, Retiring Vice President of AGU; Sverre Petterssen, Head of Department of Meteorology, University of Chicago.

of the Assembly. A number of evening functions and special excursions included evening trips by bus and by boat around the city. Weekend trips were offered to Turku, the lakes to the north, and on the Gulf of Finland. The Finnish Committee did an outstanding job in accommodating the unanticipatedly large attendance. In addition, one of the highlights of entertainment was a Sibelius concert presented twice, on successive evenings, by the Helsinki Symphony Orchestra. Indeed, so excellent was the performance that many of those who attended the first presentation sought attendance at the second.

Important features of the activity were the interesting program for ladies, and the attention given the small children who were in attendance. The Finnish group operated on the thought that if the ladies of the delegates are kept happy, so also are the delegates. The ladies' program of visits and excursions in and about Helsinki was exceedingly interesting.

Following the closing of the Assembly, excursions that extended up to seven days were arranged for parties to visit other parts of Finland, including areas in Lapland above the Arctic Circle.

Upon invitation from the United States, western United States—probably the San Francisco area—was selected as the site for the Thirteenth General Assembly, to be held in the late summer of 1963.

Administrative Report

The Council, Executive Committee, and Bureau, joined on occasion by the Finance Committee, and the Statutes and By-Laws Committee, held the following meetings during the XIIth General Assembly of the IUGG in Helsinki:

July 23: Bureau
July 25: Executive Committee, Bureau, Finance Committee Statutes and By-Laws Committee
July 25: Council, Executive Committee, Bureau, Finance Committee, Statutes and By-Laws Committee
July 30: Council, Executive Committee, Bureau, Finance Committee, Statutes and By-Laws Committee
August 1: Bureau (two sessions)
August 5: Executive Committee and Bureau only
August 5: Council, Executive Committee, Finance Committee and Statutes and By-Laws Committee
August 6: Council, Executive Committee, Finance Committee, and Statutes and By-Laws Committee

Agenda

The final agenda adopted for the Council and the Executive Committee were as follows:

1. Presentation of credentials by members of the Council.
2. Adherence of new countries.
3. Approval of the Agenda.
4. Report of the General Secretary.
5. Report of the Committee for the revision of Statutes and By-Laws.
6. Report of Liaison officers with International Organizations.
   a. Pan American Institute of Geography and History
   b. World Meteorological Organization
   c. Pacific Science Association
   d. UNESCO
   e. Cartographic Office of the United Nations
7. Report on Special Committees of ICSU
   a. SCAR
   b. SCOR
   c. COSPAR
8. Report on the 'Comité International de Geophysique.'
9. Inter-Union Commissions and Committees.
   a. Radiometeorology
   b. Ionosphere
   c. Solar and Terrestrial relationships.
10. Federation on Permanent Services (FAGS).
    a. Creation of a Permanent Service of the General Bathymetric Chart of the Oceans.
    b. Conversion of the WMO Centre of Meteorological Data into a Permanent Service.
    c. Reorganization of the International Latitude Service.

11. Report on IUGG Publications.
12. Report on IUGG Chronicle.
13. New edition of the pamphlet 'A description of the Union and its constituent Associations and Commissions.'
14. International Geophysical Bibliography.
15. Drafting of rules for symposia.
16. Report of the Finance Committee.
17. Recommendation to increase the income of the Union.
18. Report of the provisional committee on Radioactivity of Rocks.
19. Report of the Committee appointed to consider appropriate means of celebrating the Centenary of the founding in 1863 of the International Geodetic Association.
20. Report of the Committee appointed to consider the proposal made by the USSR National Committee that the IUGG establish and award medals.
21. Establishment of a Committee for the Study of Dynamics and Morphology of the Marine Littorals.
22. Adoption of the Resolutions.
23. Place and date of the next General Assembly.
24. Report of Nominating Committee.
25. Election of the Officers of the Union.
26. Policy of nonpolitical discrimination.
27. Creation of an International Glaciological Commission.
28. International Cloud Physics Conference.

Actions on Agenda Items

At the first meeting of the Bureau, discussions took place on all agenda items except 16, 17 and 25. The initial meeting of the Executive Committee dealt with all items except 1, 2, 3, 4, 5, 15, 16, 17, 18, 20, 22, 25, and 26. In the following report of actions taken, no distinction is made between Bureau, Executive Committee or Council action, except where differences occurred.

1. *Presentation of Credentials by Members of the Council*

Representatives from two German Academy groups, headed by Böhnecke, and Meisser were present at Helsinki. The Council agreed that both of these persons would be admitted to the Council meetings as representatives of their respective Academy groups only, to sit side-by-side, and to cast one vote for Germany, or to abstain, depending on whether they agree or disagree on the particular question on which a vote is required. This arrangement was ruled by the President to apply to this Assembly only and is not to constitute a precedent in governing future action. Otherwise, the presentation of credentials was routine.

2. *Adherence of New Countries*

Bulgaria, Cuba, and the Republic of Korea were confirmed as new members of the IUGG. The Council also approved the adherence of Bolivia and Mali.

The Chief Delegate of the USA proposed that immediate action be taken on the application of Taiwan to join the Union. This application has been under consideration since the last General Assembly in Toronto in 1957. He asked that this application receive exactly the same consideration as all other applications to the Union. After discussion, the Council decided to appoint a small Committee consisting of the Chief Delegates from India, Colombia, and Finland to explore the problem, and to prepare an appropriately worded resolution for Council consideration which, it was hoped, would be mutually acceptable to both the Council and the Academia Sinica Taipei. The Committee reported later, and recommended that the application from Academia Sinica Taipei be accepted, provided that the Academia would transmit the following statement to the IUGG:

> "Academia Sinica Taipei, representing only the geodetic and geophysical work under its auspices in Taiwan and associated islands, adheres to IUGG."

Despite suggestions from the Chief Delegates of the USSR and certain other countries that the matter receive further study, even to its postponement to the next General Assembly, the Committee report was accepted and a cable worded in accordance with the Committee's recommendation was sent to the President, Academia Sinica Taipei on July 30. It was agreed that upon receipt of a reply in the exact words proposed, the application of the Academia Sinica Taipei be accepted. Any deviation in wording would require approval by National Committees, presumably by mail vote. The Council agreed that all further questions on

this matter be referred to the Bureau of the Union.

By the close of the General Assembly, no formal reply had been received from the Academia Sinica Taipei.

3. *Approval of the Agenda*

The agenda given above were accepted. Three additional items were suggested, but were declined inasmuch as they did not receive the necessary two-thirds majority approval of the member countries represented in the Council, as provided for in By Law 6 of the Toronto Statutes and By Laws. The suggested items were: (1) a proposal by the Finnish National Committee that, in the future, General Assemblies in the Union be divided, providing for various groups of Associations to meet separately, in order to reduce the size of the meetings; (2) a proposal that the Union co-sponsor an International Conference on Equatorial Geophysics, and the creation of a Regional Geophysical Center at Huancayo; and (3) a proposal received from Professor Beloussov concerning studies of the Earth's upper mantle. It should be noted that the above rejections were brought about largely by abstentions. With approximately 40 Council members present, the 27 affirmative votes needed were not obtained.

4. *Report of the General Secretary*

The report of the General Secretary was accepted. It highlighted a number of important problems that face the Union, including (a) publications, (b) finances, and (c) organization.

The publication problem, as it involved the Union and the various Associations, was of such importance that a special committee was appointed by the President to look into the matter, and to make appropriate recommendations to the Council at Helsinki. This Committee consisted of V. V. Beloussov (USSR), Chairman; L. V. Berkner (USA), A. H. Cook (UK), and J. Coulomb (France). A more detailed discussion of this problem is presented under item 11.

The financial status of the Union is also a matter of grave concern particularly in view of the reduction in the reserve fund, caused by expenditures that have exceeded income for the past several years. Contributing factors include publication and travel-to-meeting costs. A further discussion on this matter will be found under items 16 and 17.

The Bureau of the Union, approved at the XIth General Assembly, held in Toronto, Canada, in 1957, met five times during the past triennium and has played an active role in administering the affairs of the Union, which are of growing complexity because of new requirements placed on the Union by the International Geophysical Year and the many new programs that have emerged from that operation. Consequently, the General Secretary has stated that he believes the structure of the Union must be reviewed carefully to assure that the Union can, in the future, play a more effective role in the planning and coordination of these activities. No specific recommendations were made, however, concerning such a reorganization.

The balance of the General Secretary's report dealt with routine matters, and it will presumably be published *in extenso* in the Proceedings of the XIIth General Assembly.

5. *Report of the Committee for the revision of Statutes and By Laws*

The Committee's report, including its recommendations for new Statutes and By Laws, was accepted. The report stated that all National Committees had been given an opportunity to comment on the draft of proposed Statutes and By Laws. The final draft reflected compromises between the comments received and Committee views, and had been developed in a series of meetings at Helsinki during the course of the General Assembly. It was reviewed in detail at the Council, and all Committee recommendations were accepted.

Because of possible editorial changes in the final text, the new Statutes and By Laws are not reproduced in this report, but the official text will be circulated by the General Secretary. Major changes from the version approved at Toronto include the following:

(a) A clarification of the roles and various Union administrative bodies, e.g. the General Assembly, the Council, the Executive Committee, and the Bureau.

(b) Provisions for a Treasurer. To keep the total number in the Bureau at seven, members-

at-large had been reduced from three to two.

(c) A simplification of the relationship between categories of membership and units of contribution. (The top category, S, now calls for 30 units of contribution. The version submitted by the Statutes and By Laws Committee set the top limit at 25 units of contribution; the Council increased this to 30 on the urgent recommendation of the Finance Committee.)

(d) A relaxation of provisions for Union financing of the travel of Union officers to official meetings in order to avoid excessive demands on Union funds.

6. *Report of Liaison Officers with International Organizations*

The Council accepted the reports of the IUGG Liaison Officers to UNESCO, the Pan American Institute of Geography and History (PAIGH), the World Meteorological Organization (WMO), and the Cartographic Office of the United Nations (COUN). The following Liaison Officers were designated by the Council for the coming triennial:

UNESCO and COUN, G. Laclavere (France)
WMO, Warren L. Godson (Canada) (Godson is the new Secretary of the International Association of Meteorology and Atmospheric Physics).
PAIGH, André Simonpietri (USA)
Pacific Science Association, E. V. Karous USSR)

7. *Report on Special Committees of ICSU*

Reports on SCAR and COSPAR have already been published in the IUGG Chronicle.

(a) SCAR. Laclavere indicated that liaison with the IUGG was satisfactory (Laclavere is President of SCAR and General Secretary of IUGG). The next meeting of SCAR is scheduled for Cambridge, England, in late August.

(b) SCOR. Union action consisted of designating five representatives. On the basis of recommendations made by the International Association of Physical Oceanography the following representatives were designated: G. E. R. Deacon (UK); K. G. G. Böhnecke (Germany); V. G. Kort (USSR); Paul Tchermia (France); H. B. Hachey (Canada).

(c) COSPAR. Final action on the establishment of an IUGG–COSPAR Committee consisted of adoption by the Union of a resolution proposed by the American Geophysical Union. The text of this resolution follows (Ed. note: Editorial changes may be made in final version as circulated officially by the General Secretary, IUGG):

> 'The IUGG, *Considering* the importance of a close liaison between its Associations and Commissions and COSPAR,
>
> *Decides* to appoint an IUGG—COSPAR Committee, consisting of as many representatives, duly nominated by the several interested associations, as are essential to represent each specialized scientific field of the IUGG, and
>
> *Recommends* that the functions of the IUGG—COSPAR Committee be tentatively defined as follows:
>
> (a) To provide a mechanism for presenting IUGG interests and recommendations to COSPAR. The members of the IUGG—COSPAR Committee are to take appropriate initiative within their associations and among their colleagues to provide such information to the Committee, and thus to the IUGG member of COSPAR. The Committee is also to serve as a focus of space interests within the IUGG.
>
> (b) To consider COSPAR agenda, which will be circulated to the Committee by the IUGG member of COSPAR, and to provide the IUGG member with advice on topics relating to the fields of interest of the members of the Committee.
>
> (c) To consider IUGG interests in space science, including experiments and symposia, which should be recommended to COSPAR for action. In this sense, the Committee, by virtue of its specialized membership, can provide COSPAR with expert scientific advice and assistance in the fields covered by the IUGG. Members of the Committee shall take initiative, working within their associations and with their colleagues, to provide scientific recommendations to the Committee and thus, through the IUGG member of COSPAR, to COSPAR."

8. *Report on the 'Comité International de Geophysique.' (CIG)*

Laclavere (France) as General Secretary of the CIG reported that two meetings of CIG have been held and a third is scheduled for early 1961 in Paris. The proceedings of the first two meetings have been published in the *IUGG Chronicle*. (First meeting, No. 28; second meeting, No. 31).

Draft rules for CIG, including changes made at the first two meetings, have been submitted to ICSU for consideration at the XIIth meeting

of the Executive Board, scheduled for Lisbon in October 1960.

One of the most urgent questions being explored by CIG in line with the first of its principle responsibilities, namely, the orderly termination of the IGY, is the matter of IGY–IGC collection and publication of data. Also considered is the question of whether or not data beyond the IGY and IGC should be handled by World Data Centers. The discipline members of CIG are studying the total problem. The Associations of the Union also were asked to consider the matter at Helsinki.

In particular, reviews are called for in all disciplines to re-evaluate earlier decisions on descriptions of nature and form of data to be supplied, formats for publication of data, whether or not collections terminate at the close of IGC-1959, or continue open-ended, how the cost of operation of individual centers will be funded, and related questions. It was emphasized that the World Data Centers requirements in data preparation, and the cost of supplying these data to World Data Centers is more than many observatories in the smaller countries can bear.

Strong emphasis is being placed on an attempt to complete IGY data collections by January 1, 1961. Attention is also being given to the problems of interim and final catalogues of World Data Center holdings.

In connection with meteorological data, the World Data Center C, operated by WMO at Geneva, has decided to discontinue operating as a collection center after the end of IGC-59 (Dec. 31, 1959). Efforts are now being made to create a permanent service for various meteorological data, but discussions between IUGG and WMO have, so far, been inconclusive. It is clear, however, that the decision must and will be made by WMO. As an interim measure, WMO has agreed to keep the Center open until July 1961.

The General Secretary stated that, under a contract negotiated with Pergamon Press, it was anticipated that IGY data publication in the "Annals of the IGY" would be carried through as a commercial venture probably without cost to the ICSU or IUGG, with the possible exception of a series of multi-color solar activities charts.

The Union adopted a resolution proposing that CIG appoint an additional discipline member for the World Magnetic Survey. The CIG also recognizes the importance of a Sunspot Minimum Program—SMP—to supplement the IGY program at sunspot maximum. W. J. G. Beynon has been appointed by CIG as coordinator to bring the principal elements of such a program together for its next meeting in January; see resolutions of IAGA.

9. *Inter-Union Commissions and Committees*

(a) *Radio Meteorology* (IUGG, URSI). A draft constitution for the Committee was approved and the following six persons were named as IUGG representatives: B. R. Bean (USA); J. S. Marshall (Canada); Pierre Misme (France); A. M. Oboukhov (USSR); Y. Ogura (Japan); P. A. Sheppard (UK).

(b) *Ionosphere* (*IUGG, URSI, IAU*). A draft constitution for the Committee was approved, and M. Nicolet (Belgium) was named as the IUGG representative to an ad hoc Committee. This Committee, consisting of a convener and one representative from each of the three participating Unions, will nominate the future membership of the Inter-Union Committee on the Ionosphere.

(c) *Solar and Terrestrial relationships* (*IUGG, URSI, IAU*). A draft constitution was approved, and two nominations submitted by IAGA were approved, namely, J. Bartels (Germany); M. Nicolet (Belgium).

Additional nominations are under consideration in the IUPAP, and will be cited in the official Transactions of the XIIth General Assembly.

10. *Federation of Permanent Services* (*FAGS*)

Laclavere, as General Secretary of FAGS, reported that, with the exception of two services, the FAGS was in satisfactory condition. The two exceptions are the *International Seismological Summary* (ISS), and the *Quarterly Bulletin of Solar Activity*. In the case of ISS, there is a publication delay of about 5 years. The Bulletin of Solar Activity is about 3 years behind.

The ISS problem was referred to the *International Association of Seismology and Physics of the Earth's Interior* (IASPEI). Efforts will be continued to secure additional funds for

increasing the ISS staff, in an effort to cut publication backlogs.

The problem of the *Quarterly Bulletin of Solar Activity* is being dealt with in the *International Astronomical Union* (IAU).

A general problem that must be faced is the tremendous increase in all geophysical data as the result of the IGY. With an estimated 2000 observatories in 67 countries sending material into the various permanent services, a significant increase in their present annual income of approximately $50,000 will be needed if prompt coverage and services are to be maintained.

Two new Permanent Services were requested, namely, a permanent service on the General Bathymetric Chart of the Oceans (GEBCO), and a meteorological data center at Geneva for continued collection of aerological ozone and radiation data, to continue the work done by the WDC of Meteorological Data under WMO.

Regarding the *General Bathymetric Chart of the Oceans* (*GEBCO*), the Union adopted a resolution recommending the establishment of a permanent service for GEBCO, federated in FAGS, and under the sponsorship of the International Association of Physical Oceanography. *ICSU* was urged to endorse this recommendation at the Lisbon meeting of its Executive Board in October.

Some discussion of the *Meteorological Center at Geneva* was included under Agenda Item 8, CIG. Further action is still a matter to be worked out between WMO and IUPAP. In the meantime, a Union resolution was adopted urging that appropriate steps, including a suitable, continuing, World Data Center be undertaken to assure the prompt and easy availability of meteorological data for research workers throughout the world.

Reorganization of the *International Latitude Service* (*ILS*) was the subject of a resolution adopted by the Union which recommended various administrative and technical actions, including more financial resources to the Central Bureau of ILS, a greater orientation toward studies of polar motions, the utilization of data from all available sources, the establishment of a small working group to formulate a definite plan for the organization of international coordination in the study of polar motion, and direction of the subsequent work, and consideration of various associated studies and equipment installations.

11. *IUGG Publications*

From the publications of the Union and the Associations stem some of the most pressing problems faced by the Union today. These may be grouped under three headings: cost, dissemination, and publication policy.

(a) *Cost*. The Finance Committee has reported that approximately 40% of Union funds go directly or indirectly into publications. This excludes the costs of the work leading up to publication, as well as efforts supplied without cost by many contributors.

(b) *Dissemination*. A second problem in publications is that there is little or no information circulated on how or where the material can be obtained. Under present procedures it is extremely difficult for libraries and agencies to obtain Union and Association publications. Some are out of print, stocks of others are difficult to find, and sales and distribution are fragmented among several persons. Delays in publications also present a serious problem. These difficulties combine to reduce the value of many of the publications, particularly of the Associations and certain of the Permanent Services, and hence to reduce the effectiveness of the funds spent for publication.

(c) *Publication Policy*. The policies of the Union and its Associations differ widely as to selection of materials and forms of publication. Editorial practices vary greatly and in some cases, the scientific quality is poor because of a lack of careful selection.

All of these factors have been recognized and discussed for many years, but the problems still exist. The President, in an effort to develop corrective recommendations, appointed a small group at Helsinki, as indicated under Agenda Item 4 of this report. The Committee's deliberations were summarized in the following resolution adopted by the Union:

> The IUGG recommends, insofar as feasible,
>
> (1) that the responsibility for the scientific content of the Union publications should rest solely with the Associations, but that the Union should arrange for the uniformity of presentation;
>
> (2) that when publishing symposia or scientific information all manuscripts, except those

specially invited, should be reviewed by a competent referee;

(3) that prior to a symposium copies or summaries of the papers to be presented should be distributed to the participants;

(4) that whenever possible, symposia should be submitted for publication to scientific journals of international standing, and that the journals should be asked to provide copies of the report of the symposium at a suitable discount;

(5) that the General Secretary examine, with the Secretaries of the Associations, the possibility of adopting not more than two standard formats, namely the international format 21 x 27 cm, and Royal octavo, so that there may be two numbered series of symposia in each Association, and therefore in the Union;

(6) that the presentation of all scientific publications of the Union be as similar as possible to that adopted for symposia and particularly to the two formats;

(7) that the communications to the General Assemblies should be classified by the Secretaries of the Associations into a number of subjects, and that each subject should be printed in one booklet, which should be edited by a scientist appointed by the Association;

(8) that the Union and the Associations set aside part of their resources for the publication of data or scientific information;

(9) that information concerning mainly administrative or representative questions should be disseminated by means of

a) minutes to National Committees or to participants in meetings,

b) brief resumes published in the *IUGG Chronicle*,

c) explanatory leaflets as deemed necessary by the General Secretary or the Bureau.

(10) that the reports of National Committees be continued, and that the National Committees be invited to print and present their reports in the format 21 x 27 cm in order to facilitate collection and binding of the reports;

(11) that each publication of scientific information should be sold by the Union for the sole benefit of the corresponding Association, and that the following free distribution be made: one copy for each National Committee, one copy for each member of the Executive Committee of the Association concerned, one copy to each member of the Bureau of the Union, and 25 reprints for the authors of articles. Also, for the publication of data on scientific information, one copy should be sent to each institute having provided part of the data or of the information.

The General Secretary reported that he hoped to have a complete listing of all Union and Association publications ready for distribution by the end of 1960.

12. *Report on IUGG Chronicle*

The Chronicle has established itself as a very useful and effective information bulletin on the affairs and activities of the Union. Over 3400 copies are distributed free throughout the world. The cost of printing a 32-page bulletin is about $200.

The General Secretary has also undertaken the publication of a series of monographs on special subjects, including symposia.

Recommendations concerning both the Chronicle and monographs are included in the resolution quoted in the preceding section (Agenda Item 11) of this report.

13. *New Edition of the Pamphlet Describing the Union and its Constituent Associations and Commissions*

This pamphlet has been published in both English and French as Monograph No. 2.

14. *International Geophysical Bibliography*

The Union's Committee on the International Geophysical Bibliography met during the Helsinki Assembly. The following Union resolution was adopted:

The International Union of Geodesy and Geophysics

(a) welcomes the increasingly good bibliographic coverage given in geodesy and geophysics by the four major general abstracting services in English, French, Russian and Spanish;

(b) recommends that Associations advise these four services on additional sources and journals to be abstracted;

(c) asks the ICSU Abstracting Board to bring all four together to facilitate their work;

(d) welcomes the increased scope of Meteorological and Geoastrophysical Abstracts and the possibility of a parallel increase in International Geological Abstracts, which will complete the coverage of geophysical subjects in English;

(e) recommends the publication of a list of existing bibliographies in geodesy and geophysics;

(f) recommends that Associations consider the future value of any special bibliographies published by them or of particular concern to them in view of the changed circumstances brought about by the improvement in the general abstracting journals and the great expense of publishing bibliographies.

15. *Rules for Symposia*

The following draft rules for Symposia were prepared in the Bureau, reviewed by the Secre-

taries of the Associations and later by the Executive Committee, and accepted by the Council:

One of the major promising activities of the Union and of the Associations is to organize symposia on subjects of current high scientific interest. To receive support from the IUGG, Symposia organized by an Association or group of Associations should meet the following criteria:

(1) The subject must be of immediate scientific interest, and it must be reasonably explicit. Although not a requirement, subjects of interest to more than one discipline are preferred for symposia organized during the period of the General Assemblies.

(2) The sponsoring Association or Associations shall notify the General Secretary in broad outline of the proposed subject of the symposium two years in advance if they wish to receive financial support. They should also provide an estimated budget for the symposium.

(3) The organizing Association or Associations may delegate their responsibilities to a recognized scientific authority to organize the symposium and for its early publication.

(4) It shall be the responsibility of the organizer(s) to arrange and publicize through appropriate channels the date and place of the meeting, to invite speakers on specific topics with a view to forming a balanced program, to send to the General Secretary for dissemination a list of titles of papers at least 3 months in advance of the meeting, to receive and edit the papers and discussion, and to be responsible for their early publication.

(5) While not mandatory, it is desirable to convene symposia that are not held during General Assemblies in places where the subject will be of particular scientific interest, or where General Assemblies are not likely to be held.

(6) Publication of symposia under one of the following forms is mandatory:

a) When possible, complete, edited communications should be printed, together with particularly pertinent discussion.

b) when subjects are in a very early research stage, so that formal papers are not feasible, a summary of the presentations and discussions may be prepared.

c) in other cases, a critique may serve as the permanent record of a symposium.

(7) Responsibility for handling and reporting upon the finances of the symposium shall be arranged in advance by the General Secretary or Secretaries of the Union or Unions concerned, the Secretaries of the Associations concerned and the organizing authority.

16. *Report of the Finance Committee,*
and
17. *Recommendations to Increase the Income of the Union,*

The inter-relationship between these two items makes it expedient to report on them under a single heading.

The Finance Committee found the Union and Association financial reports to be in proper order, with no evidence that any funds had been used for other than appropriate purposes. It was particularly complimentary of the General Secretary's books.

As the result of deficit financing over the past several years, the total assets of the Union have been reduced to about $39,000. This, combined with arrears in dues through 1959 in the amount of about $16,000, has produced a critical need for the Union to find additional income, if it is to avoid a serious reduction in its present activities. Actually, if it is to continue to meet its present and future obligations to international geophysics, the Union will need to increase its annual expenditures.

The Finance Committee estimated that a 60% increase in dues income would be required to meet present needs without drawing further on the Union's slender resources. To allow for expansion and contingencies, the Committee recommended the following actions:

(a) Increase the unit of subscription from £100 to £200.

(b) Urge countries to increase their units of subscription. Recommended increases would total 70 units, increasing the present total of 164 to 234.

(c) Increase units of subscription in the top category, 8, from 25 to 30.

(d) Obtain new members.

(e) Associations to make all possible efforts to further their scientific work by obtaining grants or gifts.

The Finance Committee also drew up a budget for the Union and Associations, based on the present annual income from membership

dues of £16,000. Provision was made for distribution of amounts above this figure which will be realized when the Committee's recommendations, or modifications thereof go into effect.

The Council took the following actions on the recommendations of the Finance Committee:

a) Unit of subscription was increased from £100 to £160. Most of the delegates in the Council reported that their respective national committees had already considered and accepted an earlier proposal made by the Finance Committee at the Executive Committee last fall that the unit rate go to £160. They therefore rejected the £200 rate and accepted £160.

b) The units of subscription for category 8 were increased from 25 to 30. It was the consensus of the Council that the Bureau could circulate the proposal for £200 subscription unit to mail ballots of the National Committees so as to allow each Committee to formulate its position after consultation with local authorities.

18. *Report of the Provisional Committee on Isotope Geology, Geochemistry, Age Determinations and Radioactivity of Rocks.*

Two highly successful symposia, one on Geochemistry, and the other on Age Determination of Rocks, were organized under the joint auspices of the *International Association of Volcanology* and the *International Association of Seismology and Physics of the Earth's Interior*. The *International Union of Pure and Applied Chemistry* was also a joint sponsor. The group proposed that the Council of the Union appoint a new *ad hoc* Committee to function through the XIIth General Assembly in 1963, to be known as the Committee on Geochemical Problems. The Council accepted the recommendation and the following Committee was appointed.

L. T. Aldrich (USA), *Chairman*
A. P. Vinogradov (USSR), *Vice-Chairman*
E. Picciotto (Belgium), A. J. Tugarinov (USSR) } *Secretaries*
Carl W. Correns (Germany)
Samuel Epstein (USA)
Bernard Gèze (France)
F. G. Houtermans (Switzerland)
S. Mahadevan (India)
K. Sugawara (Japan)
L. R. Wager (U.K.)

19. *Report of the Committee appointed to Consider Appropriate Means of Celebrating the Centenary of the Founding in 1863 of the International Geodetic Association*

A Committee was formed consisting of Professor Kukkamäki (Finland) as convenor, four members from the International Association of Geodesy, one from each of the other six associations, and four appointed by the President of the Union. The Committee is to appoint its own Chairman.

No report was received during the General Assembly.

20. *Report of the Committee Appointed to Study the Proposal made by the USSR National Committee that the Union establish award medals*

An *ad hoc* committee, with Professor Kukkamäki as convenor, one member from each Association, and Professor Heiskanen as an extra member, was appointed to consider the matter further. It has been under discussion for several years, both within the Bureau and the Executive Committee.

No recommendation for further action was received at Helsinki. The proposal will probably be handled by correspondence with national committees.

21. *Establishment of a Committee for the Study of Dynamics and Morphology of the Marine Littorals*

This question was referred to the International Association of Physical Oceanography. As a result of their considerations the following resolution was adopted by the Union:

> The IUGG, having considered the proposal for the establishment of a Committee for the Study of the Dynamics and Morphology of the Marine Littorals;
>
> Recommends that a Committee on Near Shore Oceanography be established by the International Association of Physical Oceanography with the participation of the International Associations of Scientific Hydrology, Geomagnetism and Volcanology with the following terms of reference:
>
> To gather information from individual scientists and existing organizations as to their present activities and views, to prepare a memorandum indicating the most desirable lines of future work, and to draw up plans for a symposium in this field.

The USSR National Committee has also proposed the organization of an International Commission for the Study of Modern Movements of the Earth's Crust. A symposium on this subject was sponsored jointly by the International Association of Seismology and Physics of the Earth's Interior (IASPEI), and the International Association of Geodesy (IAG). IAG has established a Commission on the subject, on which will be members from IASPEI. Further details are given in the report of meetings of the IAG at Helsinki.

22. *Adoption of the Resolutions*

The Union adopted nineteen resolutions, exclusive of the various expressions of thanks to the Finnish hosts. In addition, each of the Associations passed resolutions. This section of the report deals only with Union resolutions.

Eight of the Union resolutions have already been cited under agenda items 7, 8, 10, 11, 12, 14, and 21. In addition to these, were resolutions dealing with the following:

(a) Standard formulae for calculating refractive indices;
(b) Use of metric units;
(c) Studies of changes that can possibly occur between oceans and land surfaces;
(d) Tsunamis (data collection and warning systems);
(e) Studies of lunar influences;
(f) Rapid publication of monthly summaries of high latitude geophysical data;
(g) Publication of a quarterly "Bulletin of Volcanic Eruptions";
(h) Improvement of seismic instrumentation in certain South American countries;
(i) Coordination with UNESCO—WMO Symposium on Climatic Changes;
(j) Upper mantle studies. (This resolution urges studies in connection with the Earth's upper mantle in line with the proposal made by the Soviet National Committee. It should be noted that this proposal was one of the suggested new items declined by the Council for the Agenda.)

23. *Place and Date of Next General Assembly.*

The delegate from the United States, on behalf of the National Academy of Sciences, invited the Union to hold its 13th General Assembly in the United States in 1963. He indicated that the National Academy of Sciences will celebrate its centennial anniversary in 1963. Following this invitation, the delegate from Germany extended an invitation to the Union to meet in Munich in 1963. In an extremely gracious action this latter invitation was subsequently withdrawn by the German Delegation on the basis of the earlier date of the American invitation. The Union therefore accepted the offer of the United States delegate. The exact location and final dates are to be set by the National Academy of Sciences and transmitted to the General Secretary of the Union.

The delegate from Australia indicated, informally, the likelihood of an invitation to hold the XIVth General Assembly in Australia.

24. *Report of Nominating Committee, and*
25. *Election of the Officers of the Union.*

These two closely related items are reported together.

A Nominating Committee of the IUGG was appointed, consisting of:

K. R. Ramanathan (India), *Chairman*
Maurice Ewing (United States)
V. Laursen (Denmark)
V. A. Troitskaya (USSR)

The report of the Nominating Committee presented a single slate of candidates for Union offices. The report was accepted and the following candidates were elected:

Bureau

President: V. V. Beloussov (USSR)
Vice-Presidents: J. Bartels (Germany)
J. Kaplan (USA)
Treasurer: E. A. Andersen (Denmark)
General Secretary: G. R. Laclavère (France)
Members: M. S. Krishnan (India)
T. Nagata (Japan)

Finance Committee

K. H. Beij (USA)
M. Doporto (Ireland)
J. M. Rayner (England)
Father A. Romana (Spain)
T. J. Kukkamäki (Finland)

(It is the practice in the Union for the Finance Committee to elect its own Chairman and Secretary.)

26. *Policy of Political Nondiscrimination.*

The ICSU policy statement of political nondiscrimination was endorsed by the Council of the IUGG.

27. *Recommendation to create an International Association of Glaciology in the IUGG.*

This recommendation, made by the USSR National Committee, was referred to the International Association of Scientific Hydrology. Details of the IASH actions are given in the IASH report. Briefly, it was agreed that the Commission of Snow and Ice within the IASH, could, with the cooperation of the national committees, meet the requirements of the glaciologists, and that a new association should not be formed.

28. *International Cloud Physics Conference.*

This matter was referred to the International Association of Meterology and Atmospheric Physics which took note of the fact that a symposium on the subject is now planned by the Australians, to follow the Tenth Pacific Science Congress in 1961.

(EDITOR'S NOTE): In the following reports by Associations, the plan has been to present each report in three principal parts, i.e., (1) General, including general administrative matters, elections of officers, reports on Presidential addresses, if any, committee rosters, Association resolutions, etc.; (2) Sessional or Sectional papers and actions, comprising brief reports on technical sessions; and (3) Symposia, comprising more detailed reports on the papers and discussions involved, each symposium being reported under a separate heading and in chronological order. Sections 2 and 3 follow designations in the Official Program. Where possible, the name of the speaker and of his country have been indicated, but in a very few instances such information was not available at press time. Dates and times of meetings—obtainable from the official programs—have been omitted except where thought desirable to clarify the report.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

GEODESY

General Report

The International Association of Geodesy held Executive Committee meetings on July 25 and August 2. Throughout the period July 26 to August 6, inclusive, two plenary sessions, 33 sectional sessions, and 14 symposia meetings were scheduled; all but one of the symposia were in co-sponsorship with various Associations. However, many unscheduled meetings were also held.

The Association made plans for the formulation of two additional permanent commissions, one for geodetic uses of artificial satellites, and the other for the study of slow movement in the Earth's crust. The United States has a special interest in the work of both of these commissions, and will have several members on each.

Provisional plans were made for several symposia during the intervening three years between assemblies. One of them, on the geodetic uses of satellites, will be held in the United States, probably at Washington, D. C., in 1962.

A special commission was appointed to make a thorough study of the present structure and organization of the Association. This group was asked to report at the next Assembly.

At the first meeting of Section I, a proposal to change the name of the section was presented for consideration between Assemblies. The following names were offered: (1) Fundamental Geometric Networks; (2) Geometric Geodesy; (3) Triangulation, Trilateration, and Traverse and (4) Fundamental Trigonometric Networks. These will be considered by a commission.

ELECTION OF OFFICERS

The following Association officers were elected for 1960–1963:

President	C. A. Whitten (USA)
1st Vice-President	G. Bomford (Gt. Britain)
2nd Vice-President	J. D. Boulanger (USSR)
Secretary	J. J. Levallois (France)
Assistant Secretary	F. L. Culley (USA)
Assistant Secretary	S. Krynski (Poland)

Sections

Section I	*Triangulation*
President	A. Marussi (Italy)
Secretary	L. Asplund (Sweden)
Section II	*Precise Leveling*
President	T. J. Kukkamäki (Finland)
Secretary	L. Cahierre (France)
Section III	*Geodetic Astronomy*
President	W. Markowitz (USA)
Secretary	P. Melchior (Belgium)
Section IV	*Gravimetry*
President	D. A. Rice (USA)
Secretary	W. Grossmann (Germany)
Liason with International Gravity Bureau	S. Coron (France)
Section V	*Geoid*
President	W. A. Heiskanen (Finland)
Secretaries	K. Ledersteger (Austria)
	M. Bursa (Czechoslovakia)

Officers of previously established commissions were reappointed. Officers and members for two newly formed commissions are as follows. (Final Membership not limited to this group):

Commission on Geodetic Uses of Artificial Satellites:

President: A. H. Cook (Great Britain)
Secretary: Fred L. Whipple (USA)
Members: J. D. Boulanger (USSR)
W. M. Kaula (USA)
J. Zhongolovitch (USSR)

Commission on Movements in Earth's Crust:

President: Y. A. Mescheriakov (USSR)
Secretary: S. Miyamura ~~(USSR)~~ Japan

The Association questions the future need for details in general reports of triangulation nets, of level lines, and of detailed summary of accomplishments. The trend is now toward interest in scientific developments in Geodesy, particularly in techniques such as stellar triangulation, three dimensional Geodesy, use of Earth satellites, and the like.

Also, the need to read technical papers at Assemblies is not evident. It is suggested that a digest only should be presented, with an emphasis on general discussion. This idea presupposes that papers to be presented are in the hands of delegates well before the meetings, not simply in his mail box the evening before a meeting. Emphasis here is the urgent need for papers to be received by the Sections well in advance, in order that critical selection of the most important contributions in the field might be made, and that they may be available when the delegates report for the Assembly. A comprehensive Agenda for each Section is most useful to delegates so that they can select the meetings that are of primary interest to them.

The accounts of the IAG will be audited in Paris, in September. A committee of European delegates was named for this purpose. It was noted that the IAG may not receive an equivalent sum for publications during this coming triennium.

Frequent reference was made to the classical practice of ignoring terrestrial refraction in triangulation observations, and of not correcting horizontal angle measurements for station errors.

One could not fail to be impressed with the universal interest of geodesists in the stellar methods of positioning and azimuth determination; if nothing else can be observed, the subject of the use of Earth satellites and flares in this field will be of primary importance to IAG in the coming triennium. Such techniques permit longer distances to be measured. The resultant coordinates are not dependent upon knowing the deflection of the vertical, refraction is assumed to be less troublesome, if not entirely eliminated, and the accuracy of determinations is more encouraging than was anticipated. The Doppler technique, such as is to be used with the 'transit' satellites, was given only very brief mention. Stellar methods can be used for island connections and for checking long-range geodetic arcs of control.

It was felt that the meeting was highly stimulating and gainful, but that even more would have been derived from it if there had been an opportunity to review the papers in advance, so that discussion of the many important facets presented in them could have been more prepared and searching.

The Finnish Arrangements Committee deserves commendation for a job well done; the arrangements at the University were excellent, every need was anticipated, and the cheerful and willing helpfulness of the persons behind the services desks was outstanding.

Section Meetings and Papers

Section I: Triangulation

This Section heard a general report on Triangulation, Trilateration, and Traverse being extended in the various countries. It was not complete, inasmuch as only 25 countries submitted material.

Two of the scientific sessions were devoted to discussions of the work accomplished at the Venice Symposium, on Three Dimensional Adjustments, and at the Washington Symposium, on Electronic Distance Measuring Equipment. Additional papers relating to these special interests were presented and discussed. The report of the Special Study Group on electronic distance measuring equipment was excellently presented and well received.

The joint symposium on the Geodetic Uses of Artificial Satellites (see beyond) was outstanding. William A. Markowitz and A. H. Cook reviewed the work that has been accomplished to date.

As a result of the broad interest shown by the delegates, plans were made to create a permanent commission to coordinate the work in

this field. A detailed report on the symposium is given beyond.

Great interest was indicated in the general application of stellar triangulation through the use of satellites and flares. In addition to position fixing, proposals for determining azimuths by similar means were discussed.

The presentation of draft specifications for fundamental triangulation brought general discussion; the Association agreed to accept the specifications as guide lines. A point of great interest to geodesists in the United States is the requirement for a minimum accuracy of 1 part in 100,000 between base lines, and a similar degree of accuracy for loop closures. Many delegates asked for higher refinements but were told that the guide lines set only the minimum limits.

Resolutions and Recommendations

The Section adopted several resolutions for presentation to the Union and to the Association. A resolution to the Union proposed the adoption of basic formulas for calculating refractive index in order to achieve uniformity in the computation of electronic distance measurements. Resolutions presented to the Association included items on the use in triangulation networks of distances measured with electronic equipment, the adoption of provisional specifications for fundamental geometric networks, encouragement in research work in terrestrial refraction, application of stellar triangulation techniques to intercontinental ties and recommendations that several ties between existing networks be made or improved as soon as convenient to the participating Governments.

The resolutions adopted are:

1. Appreciating the work carried out by its Special Study Group (SSG) 19 in investigating electronic and electro-optical distance measurements methods, IAG

RESOLVES that such methods be accepted for fundamental geodetic work, provided that the instruments used have been established as having the required characteristics, and provided that the operating procedures and precautions as recommended in the report of the SSG 19 are followed, and

RECOMMENDS that when such measurements are included in the adjustment of networks the probable errors for the instruments concerned which are indicated in the report, should be adopted as a guide, and

CONCLUDES that electro-optical instruments are suitable for base measurements, and that instruments using radio micro-waves are suitable for traverse, trilateration, and for checking of scale of triangulation nets by the measurement of complete figures but *not* of bases or of single sides.

2. Considering that terrestrial refraction is of fundamental importance in geodesy and that inaccuracy of the determination of its effect creates a serious source of errors in many geodetic measurements, predominant for instance in vertical angle measurements, leveling, and distance measurements with the use of radio micro-waves, IAG

RECOMMENDS that every encouragement be given to research work in this field.

3. Considering it of importance that fundamental geometric networks be established at reasonable cost and with a uniform accuracy, sufficiently high for various scientific purposes, IAG

RESOLVES that the provisional specifications for the establishment of such networks which are given in the report to the XII Assembly by the Special Study Group 14 for the present be adopted as a guide, and

RECOMMENDS that in addition, so far as possible, and where suitable, gravity measurements be established to enable the calculation of gravimetric deflections at the stations of the fundamental net, that especially in mountainous areas frequent astro-deflection stations be established, and that vertical angle measurements be introduced throughout the fundamental net.

4. Considering it of importance that the readjustment in a scientific way of the European triangulation network be thoroughly prepared and that the net as far as possible be improved and made uniform, and appreciating the efforts to this effect which have been made within the Permanent Commission for the Readjustment of the European Triangulation Net, IAG

RESOLVES that the resolutions passed by the Commission at the Lisbon Symposium be adopted so far as the European triangulation is concerned

5. Considering that stellar triangulation will make it possible to effect accurate inter-continental connections and to establish wide-ranging networks by this means, IAG

RECOMMENDS that such methods be practically developed and improved and be used to supplement and extend conventional geodetic networks.

6. Considering the high accuracy of the standard base lines measured with Väisälä light interference comparator in Finland, Argentine, the Netherlands, and Germany, which base lines are available to any member country of IUGG, IAG

RECOMMENDS these standard base lines to be used for standardization of invar wires and tapes.

7. With the object of interconnecting various continental triangulation systems, IAG

RESOLVES that Governments concerned should be asked to carry out primary triangulation, Hiran trilateration or primary traverse as follows:

(1) revision of East Calcutta Longitudinal Series in East Pakistan
(2) between Malaya and Sumatra
(3) between Australia, New Guinea, Timor, and Somba
(4) between West Pakistan and Ethiopia, either by Hiran method through Saudi Arabia or by tellurometer traverse along the Arabian coast, or by both methods
(5) from Ethiopia through Sudan to Dakar
(6) between Algeria and Timbuktu
(7) between north Kashmir and the USSR primary triangulation system, and
(8) across the Bering Strait between Alaska and Siberia.

Section II: Leveling

The usual resumé of a General Report on Precise Leveling 1957–59, and a summary of special reports from all countries were presented.

The report of *Simonsen* (*Denmark*), on the International Commission for European Leveling, outlined procedures involved in various solutions of the general adjustment of the European Leveling Net. *M. Kneissl* (*Germany*) pointed out a correction of 0.1 geopotential for line 218 of the adjustment.

A report was made on the Liverpool Symposium of October, 1959, the objective of which was an analysis of reasons for variations in heights of mean sea level from +0.25 meters in the northern Baltic to −0.34 meters along the Italian Coast. Desirable objectives are the inclusion of the Eastern European Leveling Net, releveling of selected older lines of the Net, and strengthening of weaker portions, i.e. single old line across Sweden. A request for information from Eastern European delegates as to the possibility of their submitting leveling data to the Central Office for inclusion of their network in the General adjustment was not answered.

J. R. Rossiter (*England*) gave an outstanding paper on reduction of sea level observations and showed success in determining corrections for pressure density of sea water, for nodal tide, and for secular variations. The desirability of improving meteorological and oceanographic data was expressed.

R. Wernthaler (*Germany*) recommended that other countries follow the German practice of periodically releveling selected lines, at highest precision, over lines subject to minimum disturbance, for crustal movement determinations.

A. M. Wassef (*Egypt*) presented a report of the Special Committee on the Analysis of Errors in Leveling, recommending that methods of statistical analysis be tried out by member nations.

One meeting was devoted to reports on crustal movements found by releveling in The Netherlands, Poland, and Estonia, which indicated an annual rise of 3 mm per year along the north European Coast, and a settlement of from 1 to 2½ mm per year in southern parts of the countries involved. Local areas in The Netherlands and in the United States where large settlements have been found were emphasized.

At the sixth meeting of the Section, *J. Cieslak* reported that, although refraction and differentials between level and optical axis are the chief uncorrected sources of error in leveling, he believes these are best taken care of by appropriate methods of operation. *J. Kakkuri* (*Finland*) and *O. Simonsen* (*Denmark*) reported that their investigations of systematic error caused by the downward illumination of the southern rod (where the rod graduations present raised surfaces) indicated that such an effect is determinable, but that the effect is so small that it does not seem likely to cause appreciable error.

The following are abbreviated versions of proposed resolutions. The Section:

1. recommends that all possible means be explored of modernizing and of making continent-wide the common adjustment of European leveling;

2. recommends that means be explored of making more connections between the leveling nets of member countries;

3. proposes (as a resolution by the IUGG) that a special study group be set up to study the changes of relative positions of continents and oceans in Europe; and

4. recommends that member nations apply modern methods of statistical analysis in study-

ing leveling errors, and that Special Study Group 3 continue its investigations.

Section III: Geodetic Astronomy

Eight section meetings were held, some of them jointly with other sections in IAG and other Associations. Several very excellent scientific papers were presented and some very lively and spirited discussions followed.

Major interest was centered on the new methods of determining positions by stellar or space methods, Moon cameras, flairs at high altitude, eclipses, occulations, satellites, etc. Some recent developments of USSR show promise of greater speed and accuracy in scaling the Moon camera plates.

W. Markowitz (*USA*) presented a paper on time service, and proposed a resolution to create a new joint commission from Section III, IAG, and from IAU to study and consider improved methods of time transmission. Serious objection was raised by the French delegate to this proposed resolution, and Markowitz then withdrew his resolution with the understanding that he felt the commission is desirable, but that the improvements could be arranged by other means

A resolution was presented to request a high-altitude satellite, equipped with flashing light and devices for electronic tracking, be placed in orbit.

Section IV: Gravimetry

Section IV received reports on the activities of the International Gravimetric Bureau for the past three years, a period marked by the untimely passing of *P. Lejay*, and the assumption by *P. Tardi* (France) of the duties of Director of the Bureau. More suitable office quarters in Paris have been obtained for the staff of 4 or 5 people, some of whom are employed part-time. The Bureau, in addition to its regular activities, now publishes twice yearly a *Bulletin of Information* containing up-to-date information on worldwide gravity activities.

In view of the important relationship between Earth gravity and satellites, the Section participated actively in the Association Symposium on Earth Satellites, with special reference to determination of the Earth's gravity field from observations taken during the past three years. The discussions indicated a general agreement that these observations, even though of a relatively low order of accuracy, have a much greater weight in determination of the Earth's shape, and external gravity field, than does an analysis of the presently available surface gravity data.

Good progress was reported on the determination of absolute gravity at various physical laboratories, and several are in good agreement; however, more data are needed to insure that systematic errors can be properly evaluated. Relative gravity measurements between the various absolute stations are being improved also. In addition to the obvious importance of increased accuracy for purely physical applications, new geodetic techniques of a dynamical character will require gravity to be expressed on an absolute, rather than relative, standard.

Several new types of field pendulum apparatus were discussed. Of particular interest was the new pendulum equipment developed in the USSR, which employs six invar pendulums swinging at atmospheric pressure, and the Canadian system, which employs bronze pendulums with extremely close control of temperature.

A special study group reported on the development of the first-order World gravity network through international cooperative measurements. The degree of cooperation shown in this worldwide activity has been excellent since its inception in 1953, and the work has progressed to a point where the first adjustment can be undertaken.

Discussion on Antarctic gravity measurements by various countries indicated that, by far, the greatest difficulty was encountered in determining elevations of the gravity stations. This tends to delay seriously the publication of gravity anomaly data, as these are dependent on barometric measurements that must be carefully correlated with meteorological soundings. It was reported that all gravimetric data obtained by U. S. agencies through the 1958 season have now been processed. An interesting suggestion was made that gravity measurements should be taken repeatedly at the same sites, beginning early in the history of Antarctic operations, to help define vertical movement of the ice surface.

It was reported that the European gravity

calibration base measurements were nearly completed and the data are being prepared for adjustment. This adjustment will be carried out cooperatively by institutions in four or five countries of Western Europe, according to methods developed by a special study group attached to the Gravimetry Section. The North American Calibration base was reported as satisfactory for practical geodetic work, and in good agreement with the European standard. However, additional pendulum and gravity meter observations should precede a definitive adjustment of the North American calibration base.

Discussion of new gravity measurement techniques was divided into two phases. The first phase was arranged in conjunction with Section V (Geoid), in order to assess the potential contribution of these techniques toward the solution of geoid problems. The second phase was directed to a study of theoretical concepts in the actual working of gravity measuring instruments under influence of various types of accelerations encountered in surface vessels and aircraft. Encouraging results were reported for the LaCoste-Romberg gimbal-mounted meter, with horizontal accelerometers and associated computing systems, operated over an extensive area off the California Coast and in the Gulf of Lower California, in 500-ton ships. Developments are also encouraging with regard to the Graf-Askania surface ship meter, which requires a vertical-stabilizing system. A report was given on the aerial gravity measuring system being developed by the U. S. Air Force. It was recognized that, if this system can be brought to an operational status, it will provide mean gravity values for square subdivisions of the Earth's surface, both on land and sea, filling out gaps now existing, and enabling more accurate studies of the geoid. The operational difficulty of determining the aircraft motion with sufficient precision, rather than limitations of the meter itself, appeared to be the most controversial aspect in discussion of aerial gravity measurement.

The Section adopted 10 recommendations on the following subjects: absolute gravity determinations (2); first-order world stations (2); Antarctic gravity reference stations; European and North American calibration bases; sea gravity reference stations; suitable orbits of artificial satellites for determining the Earth's gravity field; development of national gravity networks through the use of prospecting surveys; and a proposal for extending the existing gravity profiles westward from Argentina to the Pacific Ocean.

Section V: Geoid

W. A. Heiskanen (*Finland*) and *K. Ledersteger* (*Austria*) gave detailed reports on the activities in gravimetric geodesy during the past three years in the various countries. New techniques are being developed for making gravity observations at sea and from the air, which are especially needed to get observations in the southern hemisphere. New theoretical developments tend to describe the gravity field at the physical surface of the Earth, rather than at sea level, and to avoid the controversial reductions to an artificial surface. Papers given by *R. A. Hirvonen* (*Finland*) and *Ledersteger* dealt with these new ideas. Hirvonen suggested the name 'Telluroid' for the theoretical reference surface instead of 'Terroid,' coined by de Graaff Hunter, for philological reasons. The decision was postponed. *F. A. Vening Meinesz* (*The Netherlands*) stressed the necessity of the geophysical viewpoint, particularly isostasy, to avoid systematic errors in the unsurveyed areas; the gravity anomalies should be described as deviations from the equilibrium. *E. A. Bjerhammer* (*Sweden*) developed a theoretical solution for geoid heights as a function of gravity anomalies.

A report was made by *G. Bomford* (*England*) on the astrogeodetic method (Study Group 10) and on work done by various countries in the last three years, especially the geoid sections in Italy, Greece, Iran, and along the 35th parallel in USA. Very much needed are geoid sections through West Africa and Spain. *Mrs. I. Fischer* (*USA*) reported on the extension of the European Datum into Japan and India, on the impact of the Pleistocene glaciation on the present form of the geoid, and on a World geodetic system based on astrogeodetic satellite and gravimetric data, with ellipsoid parameters of 6378160 m and 1/298.3. *W. M. Kaula* (*USA*) presented a statistical analysis of gravity anomalies, a harmonical expression of the gravity field, and a gravimetric geoid chart including satellite data; he entered the plea to use more

statistics in geodesy for a better evaluation of the results. Baussus derived from statistical analysis of isostatic gravity anomalies a value of the Earth's radius of 6378248 m ± 27 m, which agrees with O'Keefe's value obtained from lunar distance measurements. *J. Levallois* (*France*) gave a paper on the exterior gravity field.

De Graaff Hunter reported on Study group 16, on free-air anomalies as determined at the physical observation point instead of at the geoid level, on the necessity of some method for smoothing the topography to obtain a model Earth, and on the different approach by Kaula to express the gravity field in spherical harmonics. Frey presented two papers by *Szabo* (*USA*): (1) on the orientation of the major astrogeodetic systems by determining extremely accurate gravimetric geoid height and deflection for one principal and a few auxiliary points in each system; (2) on a comparison between free-air and isostatic deflections at selected points, a continuation of Rice's study in 1951. *Heiskanen* reported on the activities of the Institute of Geodesy at Ohio State University. *Vening Meinesz* stressed the necessity for assuming the existence of equilibrium as a means to describe the gravimetrically, unknown areas, with the least systematic error. *J. Levallois* stated that any kind of gravity reduction is only a mathematical interim step which, combined with the indirect effect of the redistribution of masses by the particular reduction used, leads to the same geoid waves, and found a strong correlation of these depths, mapped at various areas of the World, with magnetic and also with gravity maps.

(Joint Session with Section IV)

Tengström (*Sweden*) reported on Study Group 15 dealing with geoidal heights on the European Datum, determined by combining astrogeodetic and gravity data, particularly for the North Atlantic Tie and Greece-Egypt connection. It was recommended that more astrogeodetic and gravimetric data should be obtained. Tengstrom gave three papers: (1) on defending the classical method in geodesy, and pointing to applications of geodesy to geophysical problems, (2) on refraction problems, (3) on a geodetic model for a volcano district, to compute depth, radius, and density of the disturbing masses by studying the gravity anomalies. *K. Ledersteger* (*Austria*) discussed the dynamical and static flattening of the Earth, pointing to discrepancies with the satellite results, and concluded that there must be a serious error in the latter. There was no time for a discussion.

JOINT MEETING OF ALL SECTIONS:
GEODETIC USE OF ARTIFICIAL SATELLITES
(July 29)

W. Markowitz (*USA*) reported for Study Group 9. Requirements for a geodetic satellite were discussed. The transit satellite and the success attained with Doppler techniques were mentioned. Markowitz proposed that the Association pass a resolution expressing the need and desire for a geodetic satellite for the geometric problem. He was supported by affirmative arguments from the floor. Accuracies were discussed, and Whipple, (Smithsonian Astrophysical Laboratory representative) stated that accuracies were better than had been expected.

A. H. Cook (*Great Britain*) summarized his 'Report on the determination of the Earth's gravitational potential from observations of artificial satellites.' He stressed certain parts of the theory of satellite motion where the development is still not satisfactory. A general discussion followed from the floor.

A paper by *Zhongolovitch* (*USSR*) dealt with the Russian development of the theory of satellite motion, and the computation of orbits was presented by A. A. Mikhailov. Slides were shown of the equations for the potential and perturbations of the orbit elements. A general discussion from the floor followed.

G. Veis discussed a report prepared by Y. Kozai in which the accuracy of results being obtained at the Smithsonian Astrophysical Laboratory were summarized by Y. Kozai, and the values obtained for the first six coefficients of the potential were given.

JOINT MEETING SECTIONS I AND III
ARTIFICIAL SATELLITES
(AUGUST 1)

S. W. Henriksen (*USA*) gave a summary of his paper, which had been distributed prior to the meeting, entitled 'The Use of Artificial Satellites in Datum Connection.' His discussion centered largely on the operation and accuracy

of the Mark II Minitrack system, whose operating stations have been located in Luzon, Guam, Wake, Kwajalein, and Samoa.

O. W. Williams (*USA*) summarized his paper entitled 'The Optimum Use of a Geodetic Satellite.' He expressed a belief that electronic techniques would give as good results as optical, and that satellite perigee need not be more than about 500 miles.

H. G. Hertz (*USA*) summarized a paper entitled 'A Precise Satellite Orbit Computation Technique.' This technique is apparently a modified Krause method.

Roman K. C. Johns (*USA*) summarized his paper on determining the astronomical unit from artificial satellites of planets.

Symposia

Symposium: International Latitude Service

(With IUA; July 27 to 30)

The symposium met eight times. About twenty papers were read, which dealt with the determination of the motion of the pole and the analysis of the results. Discussions dealt with the future operation of the International Latitude Service.

The present director of the Central Bureau of the ILS, G. Cecchini, has indicated his desire to resign as of January 1, 1961. The Symposium has requested that he continue in office, or at least assure the continuity of operations, until January 1, 1962, so that the necessary action regarding a successor may be taken by the International Astronomical Union, which meets in Berkeley in 1961.

In accordance with Resolution 6, below the Symposium selected a seven-member group to establish a definite plan of organization and direct the work in the future. The USA has one member on this group, W. A. Markowitz. The President is E. P. Fedorov of the Kiev Observatory. This group has been requested to recommend to the IAU the next location of the Central Bureau. E. P. Fedorov will circulate a letter to various observatories requesting those interested to signify their willingness to serve as the location of the Central Bureau. Offers to locate at Kiev and at Washington will probably be made.

The name of the International Latitude Service is to be changed to International Polar Motion Service (IPMS).

Seventeen resolutions were adopted. These resolutions incorporate, in various forms, practically all of the recommendations made by the American Geophysical Union in May 1960 concerning the Latitude Service. In particular the present international chain, which includes Gaithersburg and Ukiah, will be continued in operation.

The Symposium has been very successful in bringing out many points of view on the problem of the motion of the pole. The solution for the continued operation of the ILS, under the new name 'International Polar Motion Service' appears to be very satisfactory.

Resolutions and Recommendations adopted by the Symposium on ILS

1. The Symposium strongly requests Professor Cecchini to withdraw, at least provisionally, his retirement, to suspend his decision until the General Assembly of the IAU in 1961, and in any case, to assure the functioning of the Central Bureau until January 1962. Efforts will be made to obtain an increase in the financial resources of the Central Bureau.

2. The Symposium emphasizes that the need for accurate polar coordinates for both astronomical geophysical purposes is greater than ever before.

3. The Symposium recommends that the northern ILS station should continue in operation with the present instruments, and with some improvement in their equipment.

4. Stressing the importance of the Carloforte latitude station, the Symposium notes with satisfaction the assurance given by Prof. Cassinis that the activity of this station will be continued.

5. The Symposium considers that the ILS should be reorganized in the future into the International Polar Motion Service, which will utilize both time and latitude observations made at both independent stations and the stations of the present ILS.

6. A small working group should be nominated to establish a definite plan for the organization of international co-operation in the study of the polar motion, and to direct the work in the future. The group should submit recommendations to the IAU concerning the future place of the Central Bureau of the ILS.

7. The Symposium recommends that the coordinates of the pole shall be given in the following forms: $x = x_0 + x_1$, $y = z_0 + y_1$, where x and y are computed using fixed initial latitudes, and x_1 and y_1 are computed using

the mean latitude of epoch. The coordinates of the mean pole of epoch are x_0 and y_0.

8. Results obtained with the ILS and independent instruments should be published in detail as soon as practicable.

9. The following problems should be investigated further: (a) Reduction to a uniform system and careful analysis of the data of the ILS, and (b) Elaboration of criteria for the precision of latitude observation and comparison, by means of these criteria, of observations made with different instruments.

10. The density field in altitude of the atmosphere about each station should be studied in order to fix the order of magnitude of accidental refraction. One such study is indispensable for the choice of a new location.

11. Preventive measures should be taken to assure equilibrium in temperature between the instrument and the air of the shelter.

12. The intrinsic properties of the instrument should be studied to avoid optical and mechanical faults.

13. Each time that there are reasons to suspect abnormal variations of the vertical, a detailed study of the local gravity field should be made to reveal the anomalies. Such a study would be useful when a new station is created.

14. An astrolabe should be installed at Mizusawa.

15. The Observatory of Quito should place in service the astrolabe that has been sent there, and it should undertake the determination of time and latitude and the observations of fundamental stars.

16. For the study of polar motion, two more astrolabes should be installed in the southern hemisphere, preferably in observatories already equipped with position-measuring instruments. It heartily endorses the plan of the National Chilian Observatory to install one in Santiago.

17. A P.Z.T. should be established by the La Plata Observatory on the latitude of the P.Z.T. of Mount Stromlo.

Symposium: Island Arcs

Reported under Seismology.

Symposium: Ocean Floor

Reported under Seismology, *Topography, Morphology, and Geology of the Ocean Floor.*

Symposium: Mean Sea Level

(With IAPO: July 30)

This symposium, held as a joint meeting of the Associations of Oceanography and Geodesy, was well attended and a number of interesting papers were presented. The most outstanding ones probably were:

I. Hela (Finland): Causes bringing about the difference between the geoid and the mean sea-level surface. In this comprehensive paper Hela discussed twenty-one factors which affect mean sea level. It is believed, however, that the procedure probably is too complex for general application.

W. Munk and R. Hallrich (USA): The spectrum of sea-level oscillations between 0.05 and 1.0 cycle per year. Instead of trying to correct separately for many factors Munk and Hallrich developed a procedure of spectral analysis of mean monthly sea level from long series of tide records. This gives smoothed mean results eliminating most of the contributions to mean sea level except those associated with the free nutation of the Earth and the effects of Earth movement. The approach to the problem is new, and the paper appears to be a significant contribution, subject to further evaluation when it is available for study.

Symposium: Recent Movements of the Earth's Crust

Reported under Seismology

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR (including Tectonophysics)

General Report

The International Association of Seismology and Physics of the Earth's Interior (IASPEI) held four business and plenary sessions, 12 sessions for presentation of topical papers and discussions, and eight symposia sessions in co-sponsorship with other Associations.

PLENARY SESSION, JULY 26, 1960; PRESIDENTIAL ADDRESS

The substance of the Presidential Address as delivered by Harold Jeffreys is as follows:

Since his earliest work, Jeffreys has searched for imperfections of elasticity in the Earth and Moon at small strains. As early as 1870 measurements were attempted of the Moon's distortion of the Earth. The first useful measurements were obtained about 1900, and much more accurate data are now being obtained as part of the IGY.

Jeffreys mentioned briefly the effect of the Earth's imperfect elasticity where the Moon's attraction on the tides slows the Earth's rotation, and the reaction accelerates the Moon. For a circular orbit under gravitation the gain of potential energy is twice the loss of kinetic energy.

A satellite has its rate of rotation reduced if it is faster than the rate of revolution, and accelerated if it is slower. When the ultimate state is reached it keeps a constant face to its primary body. This state has been reached by the Moon and Mercury and by all the satellites of Mars, Jupiter, and Saturn whose rotations are known, with the possible exception of Jupiter III. Tidal friction is the only explanation that has been suggested. This is unsatisfactory, as we need to state a definite form of elastic imperfection, and to show that it is qualitatively capable of explaining all the phenomena observed.

Reference was made to G. Darwin's work, in which the Earth is treated as a viscous liquid and in which the viscosity is changed as rapidly as possible, and to Maxwell's equation for elasticoviscosity,

$$\epsilon = P/\mu\,(1 + t/\tau)t > 0$$

where shear stress P is applied at time 0 and is kept constant. According to Euler's free-nutation theory the Earth would have a period of 305 days, if it were rigid, but actually has a period of 430 days because of elasticity. Owing to imperfection of elasticity, Jeffreys found, in 1910, that if τ were chosen to fit the secular acceleration of the Moon, the free nutation would be damped out in a few days. In 1917, G. I. Taylor thought this difficulty could be explained by the fact that the whole secular acceleration might be due to dissipation in shallow seas with strong tidal currents. This could not explain, however, the problem with the Moon and Mercury, which are believed to have never had seas. There must be some dissipation even for strains of the order 10^{-7}. To determine this order of strain, the damping of the free nutation must be separated from irregular disturbances that maintain the motion. If the motion were left to itself, and the period is 430 days, the strain lags behind the stress by an angle of 1/40. The work of D. Phillips and D. Griggs on rocks gives two solutions for a period lag of 430 days that do not provide for enough dissipation to satisfactorily explain the present rotation, if Mercury is assumed to rotate as fast as the Earth.

In an equation developed in 1957

$$\epsilon = P/\mu\,\{1 + q \log (1 + \alpha t)\}$$

C. Lomnitz avoided the difficulty in the theory of elasticoviscosity, i.e., that creep under constant stress does not tend to become constant after a long time and in the experimental results $d\epsilon/dt$ initially is infinite. To cause behavior like t^n after a long time, the law was modified as

$$\epsilon = P/\mu \, [1 + q/\alpha \, \{(1 + \alpha t)^n - 1\}]$$

The creep after a long time tends to approach infinity, but not nearly as fast as does t. Jeffreys also applied this law to the Moon, Mercury, Mars, and its satellites, and it gave satisfactory explanations of the relevant things that have happened.

He then pointed out that, to be satisfactory, a scientific law must not only explain things that have happened but it must also explain things that have not happened. The elasticoviscous law gives no encouragement to advocates of continental drift and convection currents in the Earth's shell; under constant stress it makes the rate of creep approach zero with increasing time. The shear stresses that maintain the convection currents are nearly constant, and, therefore, the currents must fall off. However, the hot columns are maintained by these very currents flowing in from below, so that, if the speeds of the currents decline, the hot columns must disappear.

One conclusion to be drawn is that the elasticoviscous law, as applied to the Earth and the inner planets, is dead, and all conclusions based on its relating to post-glacial uplift, polar wandering, continental drift, and convection currents are totally erroneous.

Plenary Session, July 27, 1960

The President reported that the following Association members had died since the last triennium: Rev. M. W. Burke-Gaffney; Prof. R. A. Daly; Prof. Gamburtsev; Prof. B. Gutenberg; Dr. A. Lee; Mme. B. Modrahova; Dr. R. Pastore; Dr. Phalem; Dr. H. Tatel; Dr. H. O. Wood.

J. P. Rothé, General Secretary, presented a detailed financial report, which was concerned primarily with the numerous publications of the Association. The publication of the ISS and the BCIS bulletins continues to tax the facilities of the Kew Observatory and the Strasbourg office. The number of pages of both these bulletins has doubled in the past few years, and a similar increase can be expected in the near future. Five monographs were issued during this triennium. Rothé also made reference to the world-wide network of standardized seismographs about which there would be further discussion at the plenary session on August 4.

Upon completion of the financial report by Rothé, President Jeffreys appointed an Audit Committee consisting of Byerly, Hodgson, and Bonelli.

In his report on the ISS, R. Stoneley again emphasized the fact that for the current publication (1952), the total number of pages had doubled in five years. Although additional part-time workers have been engaged, more help is needed if the publication is to be brought up to date. The budget of approximately $40,000 for three years is entirely inadequate.

A committee consisting of Hodgson, Stoneley, Murphy, Jeffreys, Wadati, Kondorskaya, and Willmore was appointed to investigate the budget proposal.

The Committee suggested that additional personnel be employed to expedite the compilation of data, and epicenter determinations, and to bring the ISS publications up-to-date within a year; that electronic computer methods be employed to determine earthquake epicenters; that earthquake readings be distributed on IBM punch cards; and that further impetus be given to implementing the ideas at another meeting of the Committee within a few months.

A nominating Committee for officers of the Association was appointed, consisting of Stoneley, Bullen, Jeffreys, Pekeris, Ritsema, Vesanen, Kondorskaya, and Murphy.

In a general IUGG meeting Beloussov had offerred a proposal for the conduct of future Association meetings, whereby interassociation symposia may be organized. The members of IAS were willing to consider this proposal, provided it would not prohibit the presentation of papers that are not on the agenda of the symposia. A committee, consisting of Press, Ewing, and Mognitsky, was selected to investigate the feasibility of the proposal.

Beloussov discussed the publications of the Association and suggested a committee consisting of Båth, Karus, Rothé, and Stoneley to review all publications of IAS, and to make recommendations for bringing them up to date and for improving their contents.

PLENARY SESSION, JULY 28, 1960

The session was devoted to the publication of results of the IGY.

Rothé and Hodgson submitted brief reports of the Arctic and Antarctic seismological work of the IGY. Rather incomplete reports were available from the particular stations. A committee composed of Hodgson, Rothé, Wadati, Bullen, and Stoneley was appointed to expedite the national reports.

Very little sympathy was expressed for the publication of microseismic data. It is tentatively planned to tabulate the microseismic readings that are available, and to have them distributed by the individual stations. Action as to the best means for compiling the readings will be reported by a committee composed of Hodgson, Richter, and Solviev before the end of the conference.

The editors responsible for all other subjects were requested to have their reports ready by the end of 1960.

The Commission established in Toronto to advise on the publication of the IGY results was continued until the publications are completed.

PLENARY SESSION, AUGUST 4, 1960

V. Beloussov reported on the publication of the IGY results. He recommended the continuation of Data Centers A and B for the collection of seismological bulletins, bibliographies, and other material. The data centers would also serve as media for exchanging technical data and seismograms. This was approved in a resolution drafted and reported by R. Stoneley and J. Hodgson.

Report of Nominating Committee—The following nominations were presented:

President: P. Byerly
Vice Presidents: C. L. Pekeris and E. Saverensky
General Secretary: J. Rothé
Assistant General Secretary: M. Båth
Executive Committee: A. Hales, W. Hiller, H. Jeffreys, C. Lomnitz, K. Wadati, and A. Zátopek

The report of the Finance Committee was read by Byerly, and signed by Byerly, Hodgson, and Bonelli.

The report of the International Seismological Summary Committee was given by Stoneley. It provided for a schedule for expediting the publication of the ISS in arrears (1953-1960), and reported plans for a revision of the ISS to take care of issues after 1960.

A resolution on the publications of IASPEI was presented by Båth, Karus, Rothé, and Stoneley. It proposed that *Comptes Rendus* should be more concise; that communications published elsewhere should be indicated by title only; and that *Travaux Scientifiques* should report on the two symposia, (1) The Crust of the Oceans and the Continents, and (2) The Propagation of Seismic Waves.

The following reports were presented:

(a) Report of the Commission of ISS (Stoneley, Bullen, Hodgson, Jeffreys, Kondorskaya, Lehmann, Murphy, Wadati, and Willmore)

(b) Report of Magnitude Commission (Richter, Karnik, Wadati, and Oliver)

(c) Report of Moho Project (Maxwell)

(d) Report of Upper Mantle Project (Beloussov). After approval, Ewing requested support by all interested nations.

(e) Report on Meeting on Tsunami Warning Service and Basic Research (Murphy, Earle, Disney, Soloviev, Cox, Wadati, and Lomnitz). The following members were recommended to constitute a research group: Munk, Van Dorn, Saverensky, Disney, Murphy, Cox, and Takahasi (Chairman).

A resolution supporting seismological research in South America, particularly along the west coast, was presented.

Miscellaneous Committees of IASPEI

(1) Committee on Publication of Arctic IGY Data: Hodgson, Båth, Vesanen, Murphy, Soloviev, Jansen, Miyamura, and Tryggvason. This Committee was appointed in 1959.

(2) Subcommittee for Seismicity of Europe: Karnik, Båth, Bonelli, Galanopoulos, Hiller, de Paufilis, Peterschmitt, Saverensky, and Sponheurer.

(3) Sous Commission Carpatheque: Demetrescu, Egyed, Soloviev, and Zatopek.

Sessional Meetings

SEISMIC RECORDS OF LARGE EXPLOSIONS; JULY 27, 1960

Several papers at this session dealt with

analyses of seismic data obtained from nuclear explosions. In some cases these data were contrasted with, or complemented by, similar data from chemical explosions and from natural earthquakes.

Willis and *Wilson* (*USA*) analyzed waves with frequencies between about one and 20 cycles per second from explosions with a yield range of one to 19,000 tons. They found the seismic wave amplitudes to be proportional to the first power of charge size, and inversely proportional to the square root of the distance, providing account is also taken of absorption. A somewhat different law holds for distances less than 200 km. The frequency spectra of certain explosions suggest efficient propagation for waves with frequencies of the order of 10 cycles per second.

Diment (*USA*) and others determined crustal structure south of the Nevada test site by the refraction technique, and obtained results consistent with those obtained in the area by other investigators and also consistent with gravity data. They found that, in general, larger shear waves were generated by earthquakes in Montana than by nuclear explosions in Nevada.

Båth (*Sweden*) derived the maximum recording ranges for explosions of various Gutenberg-Richter magnitudes. His results differ from the conclusions of the 1958 Geneva Conference of Experts, for Båth considered data from very quiet locations only.

Oliver (*USA*) and others summarized data on waves of periods greater than five seconds generated by nuclear explosions in the lower atmosphere, the hydrosphere, and the lithosphere. Body waves, and Love, Rayleigh, and M2 waves, were recorded under certain conditions.

Pomeroy (*USA*) discussed long-period Rayleigh waves and body waves generated by large nuclear explosions 20 and 40 miles above the air surface. Surprisingly, these explosions generated inversely dispersed Rayleigh waves corresponding to the short-period segment of the fundamental mode. These waves are not recorded when the source is a natural earthquake.

Press (*USA*) found the spectra of surface waves from underground explosions to be less rich in low frequencies than the spectra from earthquakes of equivalent magnitude. He also presented preliminary spectral analyses of the long-period waves from the recent large Chilean shock. The periods of the free oscillations of the Earth so determined agree well with theory, and with those periods obtained by other investigators.

Latter and *Martinelli* (*USA*) described a theory for the decoupling of explosive energy from seismic waves through the use of a large cavity. *Adams* and *Carder* (*USA*) reported the results of the Cowboy experiments in which the Latter theory was tested for explosions of the order of several hundred pounds, and cavities of the order of 10 feet in diameter. Analysis of the high-frequency seismograms indicate that considerable decoupling is realized in such cases.

Johnson (*USA*) reviewed the scientific results based on seismic waves generated by nuclear explosions, and suggested that, in the future, some nuclear explosions be detonated underground in such locations as to provide maximum information on the Earth's interior.

Grinda (*Monaco*) studied the propagation of seismic waves generated by a small chemical explosion in water recorded at sea and on land. The sound channel, bottom relief, and slope of the bottom near the coast are important considerations.

Birkenhauer (*USA*) studied vibrations from chemical explosions, and determined statistically the relation between charge size, distance, and damaging vibrations. He is preparing an atlas of seismograms relating to this problem.

Nanda (*India*) attributed the reverberations in the vicinity of a shot to scattering of the propagated energy, and so deduced a velocity gradient of 0.075 km/sec/km in the Earth's crust. He also proposed interaction between the wind and the ocean waves as a possible means of generation of microseisms.

Microseisms; July 28, 1960

Nothing of a startling nature was brought out at the session. The most interesting topic was presented in a joint paper by Proskuryakova (*USSR*) and her three co-workers. Tracking the microseisms originating from a Scandinavian cyclone and from those traveling southeast across the Caucasus Mountains at seven stations in Russia, Poland, and Jugoslavia, they found a striking attenuation of the microseisms passing through mountain regions. A plastic, two-dimensional scale model of the region was constructed, using an ultrasonic source as wave generator.

Measurements of wave amplitudes were made at seven points, approximating the positions of the seven stations. Wide discrepancies were noted in attenuation between those of the model and those of the natural stations. This was naturally interpreted as caused by the fact that the model, though simulating the land elevations, was homogeneous, whereas the natural terrain was far from homogeneous. A second non-homogeneous model was constructed, using different plastics to simulate the sedimentary layers, and the almost vertical boundaries where they existed. Attenuation figures from this model agreed strikingly with those in nature.

Of the other papers, some adduced confirmation of the Longuet-Higgins standing wave theory as the source of microseisms; others rejected it as having no confirmation. None of the evidence was convincing. Japanese work is inclined to favor the inability to detect hurricane sources by microseisms until the hurricane nears land. Some excellent work was reported from the National Institute of Oceanography at Wormley, England, by *J. Darbyshire*, using electronic seismographs of period 1 to 10 secs and 18,000 magnification. Four causes of microseisms observed in England were listed: (1) intensification of storms; (2) rapid passage of a storm; (3) refraction (focusing effect) of microseisms from storms at sea; and (4) waves pounding on the shore. Factor No. 3, focusing due to refraction, was analyzed and claimed to be a significant factor in microseismic observations.

Constitution of the Continental and Oceanic Crust; July 29, 1960

B. Bogert (*USA*) described spectral analysis of waves from the recent Chilean earthquake recorded on a long-period seismograph with digitalized output. Spectral peaks were found between two- and 60-minute periods, several in excellent agreement with free vibration periods as reported by F. Press. Frequency response and filtering in the system were discussed by F. Press and A. Hales.

M. Båth (*Sweden*) suggested that differences in crustal layering and velocity structure observed by various investigators, using explosion methods, are the results of varying methods of interpretation, and that there is no real evidence of differences between continents. There was extensive discussion by Jeffreys, Hales, Willmore, Meyer, Riznichenko, Bullen, Kosminskaya, Båth, Egyed, and Byerly, several of whom believed that real crustal differences do exist.

P. L. Willmore (*Canada*) presented a method of analyzing seismic refraction data from many azimuths and distances, using 'time terms' that depend on conditions at the shot points and the receiving stations. These time terms may be evaluated by the proper selection of shot and receiving points.

J. Riznichenko (*USSR*) read a paper by *G. Tvaltvadze* (*USSR*), in which the use of near earthquakes for the study of crustal structure was discussed. Results from two Georgian earthquakes show reasonable results, encouraging further application of the method.

A. Treskov (*USSR*) described the teleseismic measurement of crustal thickness by means of reflection incident on the base of the crust from below. A crustal thickness of 40 km was found for central Africa. *Jeffreys* remarked on the difficulty of recording this phase.

L. Migaux (*France*) presented results of resistivity measurements on the Mortagne granite massif in France. By increasing electrode spacing, depths up to 70 km were probed. A highly resistant layer, with its upper surface about 7 km deep, was discovered.

G. P. Woollard (*USA*) presented evidence that most regional isostatic gravity anomalies are caused by density variations in the crust, the Archimedes principle still holding. By combining Bouguer and isostatic anomalies, a good estimate of crustal thickness may be obtained. Application to Antarctica shows a nearly continental crustal thickness (28 km or more) wherever measured, even in the deep ice-filled trough of West Antarctica.

S. Treves (*USA*) discussed geologic field evidence from U. S. IGY operations in Antarctica. There is probably a continuous horst running from Victoria Land to Coats Land. Volcanic mountains in northern Marie Byrd Land may form part of the circum-Pacific belt. Nunataks north of the horst show no evidence of the previously supposed graben.

C. Lomnitz (*Chile*) read a preliminary description by Ponce of gravity measurements currently being carried out on Deception Island, in the South Shetland Islands. Some sharp Bou-

guer anomalies, not related to surface features, have been discovered.

The first part of a two-part paper by *J. E. Oliver, G. H. Sutton,* and *M. Ewing* (*USA*) presented seismograms from the IGY World long-period network. The characteristics of a number of seismograms from almost purely continental paths were explained through reference to various portions of a typical continental dispersion curve. Additional characteristics of the long-period waves can be accounted for by propagation in a surface wave guide portion of the path, including later characteristics of compressional and shear phases.

The utilization of both Raleigh and Love waves by Öcal, through the nomograms of Sato, has produced data on crustal thickness for a two-layered crust consistent within themselves to about nine per cent (27 to 30 km).

Some of the general results of the massive effort of the USSR to resolve crustal structure through the application of the explosion technique were presented in a paper by *I. Godin* (*USSR*). Overlapping profiles in line (with shot points 40 to 80 km apart, and geophones at 1 km apart) apparently produced the same number of major crustal layers throughout. Two were shown (lower layer divided) for the entire line (≈ 3000 km) traversing the Russian Plateau, the Pergham intermountain region, Turkmenia, and Bukhara. About 40 km in the Plateau and up to 55 km in the Pergham depression were reported. Mountains along this line (Pre-Urals, and Spurs of Zeravshan) did not depress the Moho. The boundaries of the major crustal layers above Moho were shown to be depressed in areas of crustal thickening to about the same extent as Moho.

Observation of Love wave dispersion by *D. Sukharulidge* (*USSR*) from the records of the Tbilisi Observatory, Georgian SSR, has allowed crustal thickness estimates to be made for paths from the Philippines, Japan, and Africa. A two-layer crust was postulated, with a thickness ranging from 40 to 55 km.

Three areas of North America—the Mexican Plateau, the Mississippi Embayment, and the Canadian Shield (Wisconsin)—were used by *J. Steinhart, R. Meyer,* and *G. P. Woollard* (*USA*) to illustrate the evolution of analysis techniques for the determination of crustal structure from explosion data. The compatibility of reflection and refraction data was used as a criterion for the elimination of models plausible from refraction data alone. The statistical confidence-limit concept, for the estimation of the minimum uncertainty in a set of refraction measurements, was applied, owing to the lack of fit of the experimental time-distance points to least-squared time-distance lines. Errors introduced by using single-ended profiles, by neglecting surface layers, and by the method of calculation (time intercept, critical distance) were illustrated.

Preliminary results of two explosion seismic determinations in Montana, by *R. Meyer, J. Steinhart, G. P. Woollard,* and *M. Bonini* (*USA*), show that the crust is thicker under the high plains east of the Rockies than under the mountains; standard travel-time plots, as well as an actual record section from eastern Montana, were displayed. Current techniques and instrumentation (shots in 30 ft. of water) allowed small charges of 1000 pounds to be used for ranges up to 350 km in most areas. Detailed single-ended profiles can be accomplished in less than two weeks. The details of current practice were discussed. The results in Montana are in essential agreement with those of the *Carnegie Institution of Washington, D. C.*, recorded at right angles, and in cooperation with the Montana program.

The preliminary reports of the *Commission Seismologique Europeanne* showed that great progress is being made in a large cooperative explosion seismology experiment still under way. Arrivals involving all shear paths have been recorded. Three separate groups are working on the analysis of the data.

Constitution of the Continental and Oceanic Crust (continued); August 1, 1960

According to *F. Press* (*USA*) by combining three types of measurements, namely, surface-wave phase velocity, seismic refraction, and gravity, it is more difficult to obtain a single crustal model to explain the combined data than for any of these alone. In this manner, a fairly unique structure can be obtained. Examples from California-Nevada, and from Easter Island to California, indicate the power of combining these methods in determining crustal structure.

Crustal structure in western Iceland, determined by *M. Båth* (*Sweden*) from explosion

refractions, is 21, 15.7, and 10.0 km thick, with velocities of 3.69, 6.71, and 7.18 km/sec, respectively. A high-velocity lava layer within the sediments along a central profile attenuated the symbols greatly, making detailed solution responsible.

Some examples of oceanic Love and Rayleigh wave dispersion recorded on IGY long-period seismographs show features, all of which can be explained by normal wave propagation. High-frequency Rayleigh waves, previously unexplained, can be explored as M_2 waves, when low-shear velocity sediments are considered. P_L waves are leaky mode M_2 waves.

A. G. Averiamov, E. T. Galperin, I. P. Kosminskaya (*USSR*), and others reported on deep seismic soundings carried out during the IGY in the zone of transition from the Asiatic continent to the Pacific Ocean. Refraction results show the transition from continental to oceanic crust near Kamchatka. Sediment thicknesses of 10 km were found in intermediate regions. Theoretical 'headwaves,' and ordinary refraction and reflection amplitudes, agree quite well with experiment.

Results of seismic refraction measurements in the southeastern part of the Caribbean Sea show a thick sedimentary section (12 km) under the Cinacao Ridge. Detailed crustal sections N-S and E-W were shown.

Results of seismic refraction measurements north of Puerto Rico were given by *E. Bunce* (*USA*) in a N-S section through the trench and Outer Ridge, and into Nares Abyssal Plain. Much greater detail on this structure is now available. General results are similar to older sections.

Results of seismic refraction measurements in the western Mediterranean Sea, by *D. Fahlquist* (*USA*), show 8-km depth to a 6.6 km/sec layer below sediments, and a total depth of 11 to 12 km to a 7.7 km/sec horizon where the water depth is about 2.5 km.

Love waves recorded in the Crimea from East Indian shocks, for both direct path and path through anticenter, agree with the theoretical dispersion for a 40-km crust under the continental portion of the path. The theory is based on a simple one-layer case, with 3.5 and 4.5 km/sec for shear waves of the layer and the sub-crust.

Seismological Geography and Energy of Earthquakes; August 1, 1960

E. Savarensky (*USSR*) deduced energy radiated from earthquakes, assuming all the energy to be in P and S waves. The results agreed well with energies derived from the Gutenberg relationship using magnitudes determined by surface wave amplitudes.

I. Paseshnik (*USSR*) discussed the seismicity of the region around Antarctica. Three fault plane solutions suggested an upward movement of the southern side in each case. Surface wave dispersion indicated oceanic structure between Australia and Antarctica, and continental structure for Antarctica itself.

J. Vanek (*Czechoslovakia*) and *J. Stelzner* presented data from four European stations that suggested a systematic deviation between magnitudes determined from surface waves, P waves, and S waves. This deviation is a function of magnitude. Amplitudes of body waves vary with distance in a more complex manner than is usually assumed.

C. Lomnitz (*Chile*) discussed recent Chilean earthquakes (May 21–22, 1960) in the light of the known seismicity of Chile. Various macroseismic effects, such as damage to buildings, landslides, subsidence especially in coastal areas, and tsunami destruction, were illustrated. Contrary to popular reports, no new volcanoes were formed; an old volcano erupted 24 hours after a large shock. With one possible exception in the north, preliminary studies indicate general subsidence of the ground.

C. Bentley (*USA*) discussed seismic methods of reflection and refraction shooting in Antarctica, and associated abnormal surface noise, increase of energy production by hole springing, amplitude variations with distance, and dependence of shear wave velocity upon poralization were discussed.

E. Peterschmitt (*France*) (unlisted) reported on results of several seismic refraction profiles near the Antarctic coast at the Belgian Roi Baudouin station. An ice thickness profile running inland from the coast to the mountains showed rock surface mostly below sea level.

Seismic Wave Propagation; August 2, 1960

K. E. Bullen (*Australia*) presented a new method for refining the details of earthquake

travel-time waves. Important discussion of this paper centered on showing that wave-amplitude variations are not a good measure of the presence or absence of low-velocity zones, as has been assumed in the past.

J. C. Harrison and *N. Ness* (*USA*) presented observations of the Earth's free modes at UCLA using a La Coste-Romberg Earth-tide gravity meter. The Chilean earthquake of this year appears to have excited free radial vibrations in the Earth, which have been recorded at UCLA and at Pasadena. Possibly other free vibrations were also excited. The discovery of these modes, confirming Pekeris' theory, appears to be one of the most exciting developments of this triennium, judging from the amount of discussion it stimulated.

B. A. Bolt (*Australia*) gave a report of epicenter determination by electronic computers, a method that threatens to replace the present ISS procedure. For a few minutes of computer time, all the data on one earthquake in the summary are obtained. This procedure is expected to be in routine operation on data currently gathered by the U. S. Coast and Geodetic Survey.

F. Press (*USA*) described his method of making model studies. A two-dimensional model, with section, can be devised for both velocity and density of the rocks. Considerable interest was shown in his techniques of building the models, which appear to have succeeded where other methods have failed.

S. D. Kogan (*USA*) used American nuclear explosions with known origin times and depths to check earthquake travel-time curves; he obtained good agreement with Jeffreys-Bullen tables.

Amplitude studies of explosions and earthquake waves were presented in two papers. The first paper covered observations in a simple region where an attempt to check theory could be made. The second paper dealt with the Sea of Okhotsk region where conditions are more complete.

B. F. Howell, Jr., (*USA*) reported measurements of dependence of absorption of surface waves, in rocks, upon frequency within a few hundred feet of a source. This was one of the few papers presented in the IAS on small-scale studies.

C. Lomnitz (*Chile*) and *J. R. MacDonald* (*USA*) reported on the absorption of earthquake waves. Absorption is less in the mantle than nearer the surface. Mantle conditions are so different from conditions that can be duplicated in the laboratory, because of the long relaxation times of the rocks, that it is hard to compare actual Earth and laboratory data.

Fault Plane Work and Source of Energy; August 3, 1960

Three general topics were discussed in this session: (1) theoretical questions of focal mechanism; (2) techniques of interpreting data from observations of body and surface waves; and (3) studies of regional stresses. The problem of the single couple versus the double couple was mentioned frequently, and remains unresolved.

The first paper, read only in abstract, took into account both slippage along the fault and friction. The resulting mathematical model is not equivalent to any more simple model. It also indicated a dislocation theory to require a state of stress before faulting, which is not likely in the real Earth. On the other hand, another application of dislocation theory obtained a displacement field equivalent to that produced by the principal stresses relieved by faulting. These results correspond to other theoretical work presented in other papers, in which earthquake foci were represented by stress distributions suddenly applied or relieved. Study of three principal stresses, resulting in a departure from orthogonality, and in some conditions of producing non-planar nodal surfaces, may explain some earthquakes for which ordinary methods do not yield a solution. It was also noted that tabulations of fault plane solutions in terms of principal stresses give information over and above that given by testing only the parameters of the nodal planes. Application of the theory of probability makes it possible to determine nodal planes of P by statistical methods.

The polarization of S waves seems to favor a single couple for certain earthquakes of the North Pacific and of southeast Asia. In a very few instances the combination of S and P wave data indicates that a single force or dipole without moment may be operative in some earthquakes. The use of surface waves in mechanism studies makes it possible to determine either the

source function from the form of the energy propagated in different azimuths, or the phase of the disturbances at the source. These methods open a new and highly promising approach.

Several different, and sometimes divergent, methods have been applied to studies of regional stress. Definite results await more data, but the general conclusions indicate regional stresses transverse to structural features.

Continued study, both of theory and of observations of *S*, amplitude values, and of surface waves are required in fault plane work.

Instruments; August 4, 1960

Several new developments in seismological instrumentation were reviewed by *J. H. Hamilton* (*USA*). These include three new short-period ($T \simeq 1$ sec) seismometers; a new galvanometer-input, phototube-type amplifier; two recording techniques, one using 16-mm film (automatically developed) and another using heat sensitive paper; a new crystal-controlled timing system; and the use of an auxiliary coil for remote calibration.

Sample seismograms and response curves were used by *G. Sutton* and *J. Oliver* (*USA*) to compare long-period seismographs operating with various values of coupling and damping. Very high sensitivity at periods near 50 seconds were obtained, using tight coupling. An instrument using an electrometer and displacement transducer was discussed. Long-period noise is sometimes produced by thermal instability in the seismometer case; this is easily reduced by heating the top of the case.

P. Pomeroy and *G. Sutton* (*USA*) showed seismograms that illustrated the effectiveness of using galvanometers to reject five- to seven-second storm microseisms. Seismographs using these filters now are operating at about ten times higher magnification than was formerly possible.

P. L. Willmore (*Canada*) described a wide-band seismograph system, with output recorder on magnetic tape. Response flat to Earth velocity from about one to 800 seconds is obtained by electronic feedback, and components can be added together to obtain radial, transverse, and vertical components for any azimuth.

Spectrum of background noise was shown by *A. G. Moskvina* and *N. V. Shebalin* (*USSR*) for period band of 0.1 to 10 sec. Average background at a period of 6 sec was 0.2 to 2μ. At a period of about 0.3 sec, the background was 0.1 to 0.8μ. Noise level between these two periods was well below 0.1 micron. A seismograph having a response characteristic with the inverse of the noise was described.

An ocean-botton seismograph using a frequency-modulated sonic beam for signal transmission between the bottom and a surface ship was described by *B. Luskin* (*USA*) and *J. Ewing* (*USA*). The advantages of an ocean-bottom location such as the low-noise level, the possibility of studying waves propagated over oceanic paths and microseism generation, and more uniform distribution of seismic stations were pointed out. Records from a seismic refraction line recorded on the bottom seismograph illustrated some of these advantages.

Internal Constitution of the Earth, August 5, 1960

F. A. Vening Meinesz (*The Netherlands*) showed how convection currents in the mantle can explain simultaneous tension and compression in the crust. Harmonic analysis of oceanic and continental topography shows great similarity between higher order spherical harmonics, as calculated, and those to be expected from convection. The linearity of geosynclines, and their north-south trends, were cited as further evidence for mantle convection.

J. Dorman (*USA*), *M. Ewing* (*USA*), and *J. Oliver* (*USA*) presented the results of mantle Rayleigh wave studies, using a comparison of data by Ewing and Press, combined with data by Sutton and others, for the shorter period oceanic arrivals. The existence of the low-velocity layer in the mantle, and differences in mantle structure between oceans and continents, were demonstrated.

K. Aki (*Japan*) and *F. Press* (*USA*) compared observed seismograms with seismograms computed on the basis of theoretical dispersion properties of several models of the crust and mantle. This provided a method of choosing between similar models for various crustal types.

The bottom of the low-velocity layer beneath Europe and northeastern North America, at a depth of 220 km, was shown by *I. Lehmann* (*Denmark*) to be a first-order discontinuity. This discontinuity produced late reflected ar-

rivals at distances as small as 9° which were previously unexplained.

M. Landisman (*USA*), *Y. Sato* (*Japan*), and *M. Ewing* (*USA*) presented experimental and theoretical data on long-period Love waves. Group velocity comparisons show that mantle shear velocity decreases from 4.65 immediately below the mantle to a minimum value of about 4.3 in the upper part of the mantle, before increasing at greater depths. Velocity decreases at a shallower depth beneath oceans than beneath continents. The relations of these results to other physical properties of the mantle were discussed.

L. M. Malakina (*USSR*), *H. I. Shirkova* (*USSR*), and *A. V. Vvedenskaya* (*USSR*) demonstrated the anisotropic properties of various regions of the mantle by a study of amplitude ratios of P, SV, and SH waves for rays having their turning points at various depths.

V. A. Magnitsky, N. V. Kondorskaya, V. Khorosheva, and *V. Zharkov* (*USSR*) demonstrated that two-dimensional spreading of body waves implied the existence of a channel in the upper mantle. Of three possible explanations for the low-velocity layer, the only one advanced was vitrification of material in this region.

L. Egyed (*Hungary*) gave three papers concerning the consequences of the Dirae-Gilbert equation, and a decreasing gravitational constant. Phase transitions under decreasing pressure lead to an expanding Earth. Detachment of a planetary mass occurs at the equator of the Sun whenever the centrifugal force exceeds the decreasing gravitational attraction. The low-velocity channel of the upper mantle is due to the sum of the effects of decreasing basicity and increasing pressure downward in the mantle.

D. Tozer (*USSR*) presented evidence for an upper mantle orthorhombic-cubic phase transition zone for fayalite and other olivines. A very large coefficient of thermal expansion in the transition zone may govern vertical movements of the crust. The circumstances favor mantle correction.

B. P. Belikov's (*USSR*) paper, read by *Y. V. Riznichenko* (*USSR*), presented experimental data relating Young's modulus to rock porosity measured by a static method. He found that the main factor governing elastic properties is mineralogic composition.

Mathews (*USA*) described work by *Overton* (*USA*) at the Naval Research Laboratory, who made new assumptions on physical conditions in the core in order to calculate a conductivity distribution for the core. The relations to convection and other processes in the core were discussed.

SEISMIC WAVE PROPAGATION; AUGUST 5, 1960

Stephan Mueller (*Germany*) compared techniques of analyzing dispersed wave trains, including Fourier analysis, stationary phase analysis, vibralyzer techniques, and electrical analogue techniques.

James Dorman (*USA*) described the investigations of long-period surface waves, which required the existence of a low-velocity channel. He also showed that in oceanic dispersion the mud layer has an important effect on the first shear mode, and that by varying the parameters in this layer it is possible to bring the theoretical first shear mode dispersion curve into agreement with observation.

John Nafe and *James Brune* (*USA*) presented the first observation of mantle Rayleigh wave-phase velocity in the period range 100 to 650 seconds, and described how these observations were made. The observed curve was in fair agreement with theoretical computations made by Pekeris in the period range 100–400 seconds.

Mark Landisman (*USA*) presented theoretical computations of torsional vibrations in a round Earth, including the effects of sphericity, liquid core, gradients, and all internal interfaces.

George Sutton (*USA*) described theoretical and observed motion near the Airy phase for the oceanic group velocity maximum, and stated the error that might be expected from ordinary group velocity analysis.

Keiti Aki (*Japan*) described a numerical technique for using the Bendix G-15 to compute phase and group delay times for any path on the Earth.

Symposia

SYMPOSIUM: GEOCHEMISTRY

Reported under International Association of Volcanology

SYMPOSIUM: ROCK AGE DETERMINATION

Reported under International Association of Volcanology *Radioactive Ages of Rock Systems.*

SYMPOSIUM: ISLAND ARCS

In opening, *F. A. Vening Meinesz* (*The Netherlands*) expressed his personal gratification on this occasion.

V. Beloussov and *E. Rondich* (*USSR*) presented the concept of island arcs as due to 'oceanization' of continental margin areas in the latter part of geological time. It was illustrated by a tectonic map of the world, drafted by Beloussov. The arcs are tensional features, associated with basaltic volcanism. They are of two main types: (1) arcs similar to those on the mainland (Himalaya, Verkhoyansk, etc.), formed originally in geosynclines surrounding central masses, which then subsided leaving depressions interior to the arcs—such arcs are those of the western Mediterranean, the Caribbean, Indonesia, and Japan; and (2) arcuate forms due to tension accompanying deep fracturing, as in the Aleutian, Kurile, Ryukyu, and Marianas arcs. These are younger than type 1.

The Earth evolves by differentiation in the mantle due to successive melting during the process of heating of an originally cold Earth. Differentiation proceeds more slowly at the greater depths. Purely mechanical currents are insufficient to account for the facts, and change of state or material is involved.

Papers presented by *J. Nennion* (*USA*) and *M. Talwani* (*India*) dealt with seismic and gravimetric evidence, respectively, for structures in Puerto Rico and Caribbean areas, and the Tonga Trench. In the Caribbean area, the Moho is at oceanic level in the basins, but descends to continental levels under the ridges. Thus it descends from shallow level under the Yucatan Basin to a continental level, not quite reached by seismic sounding, under the Cayman Ridge. In the Cayman Trough, the Moho is again at 11 km, and under the Nicaragua Rise it descends to a deep level. Levels are 14 km in the Venezuela Basin and 20 km in the Colombia Basin. Under the Puerto Rico Trench the Moho is at shallow level, so that the crust is thin, and the negative gravity anomaly is due to thick sediments. Under Puerto Rico the Moho descends beyond the seismic exploration range, but the gravimetric data, allowing for the sediments in the Trench, indicate a depth of nearly 30 km.

In the Caribbean area crustal velocities for P waves are 6.3 to 6.5 and 7.3 to 7.5 km/sec.

The Tonga Trench is comparable to the Puerto Rico Trench, but the negative anomalies are more nearly along the trough itself, requiring a ridge masked by sediments.

A paper on the structure of the Earth's crust in the region of the Kurile Island arc and the adjacent portions of the Pacific was presented by *I. P. Kosminskaya* (*USSR*). On the basis of travel-time curves, the region is divided into three areas. Continental structure is found in the area surrounding Kamchatka, including Paramushir. Oceanic structure is found to the east. A belt of continental structure occurs east of Hokkaido and the southern Kurile Islands. An intermediate structure includes Hokkaido and the whole Kurile chain south of Paramushir, as well as a strip eastward from Hokkaido, between the belt of continental structure and the eastern oceanic area. The deeper part of the Sea of Okhotsk, close to the Kurile Islands, is in the area of intermediate structure, but the surrounding portion under the sea is of continental structure.

A paper by *E. P. Fedorov* (*USSR*) and others presented preliminary results of a detailed seismic investigation of the southern Kurile Islands. Five special stations were operated in the southern Kurile Islands, as part of the IGY program. The velocity in the upper part of the crust for P waves was found to be 6.1 km/sec. The Moho was found to descend from a depth of 30 km east of the islands to greater depths below them. Absorption of energy was greater in the depth range 30 to 85 km than in the range 30 to 45 km, suggesting that liquid material exists at the greater depths. Hypocenters were found descending westward toward and under the islands, in the usual manner in Pacific arcs. Hypocentral depths ranged from 30 to 120 km.

R. W. Fairbridge (*USA*) gave a paper on the Melanesian border plateau (principally the region of the Solomon Islands). This plateau is not considered to be a typical arc structure, the depressions being interpreted as grabens arranged in echelon, associated with strike-slip, rather than as foredeeps. No discussion of the seismic evidence was given.

A paper by *G. S. Gorshkov* (*USSR*) on the petrochemistry of volcanic rocks was read by Mme. Lyubimova.

A paper by *J. P. Rothe* (*France*) was in accordance with a resolution at Toronto favoring an atlas of seismograms of volcanic earthquakes. Those having such material were requested to make it available now.

Symposium: The Ocean Floor

Reported under International Association of Physical Oceanography. (*Topography, Morphology, and Geology of the Ocean Floor.*)

Symposium: Tsunamis and Storm Surges

Reported under International Association of Physical Oceanography.

Symposium: Recent Movements of the Earth's Crust

Co-sponsored with International Association of Geodesy, August 3 and 4, 1960.

The Secretary, *P. J. Melchior*, presented a 365-page report concerning Earth tides. He noted that the following five developments have been important during the last five years:

(1) Gravimeters have been brought to a high precision of about 1 microgal.
(2) Horizontal pendulums may achieve a sensitivity of 0.0005 second of arc.
(3) Better facilities and methods of reducing data have been introduced.
(4) New methods of harmonic analysis have been used.
(5) Electronic computers are playing a major role in solving tidal problems.

The quartz tiltmeters of Jobert (Paris) and of Verbaandert-Melchior (Brussels), and the large 80-meter pendulums of Marussi in Trieste were mentioned. Tilt results are still rather unsatisfactory and inaccurate, but improvements can be expected. The main problem is a stable site foundation.

Melchior reported also on the results of gravity tide observations carried out at many stations, ten of which obtained more than 500 days of observations. These give a mean value of $\delta = 1.190$. The 12 world-wide stations of the University of California gave a mean value of $\delta = 1.185$. However, for central Asia, Pariesky reported a mean value of $\delta = 1.14$ for three stations, and for New Delhi the UCLA found a mean value of $\delta = 1.15$.

A comparison of Dodson-Lennon and Secalozet methods of harmonic analysis showed differences at Wake, Naze, and Aso, of the order of 1 to 1.3% in M_2, S_2, and 2 to 7% in K_1, O_1.

Observations of Earth tides in water wells were noted.

The value of Love number k obtained from tidal term in length of day is 0.38 to 0.07. This was said to be in agreement with results obtained by UCLA.

Instrumental points relating to tiltmeters were also discussed. *Parŭsky* (*USSR*) reported results on $\delta = 1 + h - 3/2\ k$ (h and k = Love numbers) at the central Asian stations in Ata, Taschkent, and Lantjoou (noted above as $\delta = 1.14$), perhaps indicating regional effect.

R. Tomaschek (*Germany*) summarized work indicating tilt; it was questioned from the floor whether observations are sufficiently reliable at this stage.

A brief discussion was given by *G. W. Lennon* (*Great Britain*) of the great effects of water tides at Bidston.

L. B. Slichter (*USA*) presented a ten-minute report giving the following conclusions:

(1) Values of the Love numbers k and h for the equatorial bulge may be obtained from observational data. Geometrically the bulge represents the same type of deformation as the M_2 tidal deformation, but is of opposite sign. Although the Love numbers for the bulge are threefold larger than for the tidal bulge, the ratio k/h in the two cases are nearly the same on the basis of Earth model values, computed by others, for k and h; k/h is close to 0.47; $0.46 < k/h < 0.50$. This relation permits evaluation of k and h from gravity tide data alone.

(2) The recent satellite results for the external gravitational potentials are consistent with an essentially fluid Earth, of flattening $\epsilon^{-1} = 297.434$, $a = 6{,}378{,}290$ m, that is, they are classical values. The surface so defined departs from an equipotential surface by only +16 meters at the pole, +4 meters at the equator, and zero meters at latitude 35.3°.

(3) A significant error was noted of a factor between 3 and 4 in estimating the energy loss associated with the phase lag of the M_2 bodily tide.

Studies of tide-gage records, repeated leveling

lines, and geomorphological observations indicate that for Europe:

(1) The average rate of vertical movement of all the coasts is a subsidence of 1.1 mm per year.

(2) The northern part, England through Fenna-Scandia and into northwest Russia, is being elevated. The central part—The Netherlands and probably continuing to western Poland and the southern part of Europe—are subsiding.

More detailed studies, especially by dating post-glacial river entrenchment, show considerable complexity, but much of the pattern of uplift is coincident with positive structural elements, at least in northwestern Russia. There are, however, notable exceptions of uplift patterns crossing structural trends.

In particular, the glacio-isostatic factor was significant only for six to seven thousand years after melting of the Pleistocene glaciers. Internal tectonic processes then became more important.

(August 5)

A published report by Innes of Canada was summarized, giving about 700 gravity observations in the vicinity of Hudson Bay. The data are interpreted as consistent with the observed post-glacial uplift.

C. A. Whitten (*USA*) reported on the results of recent geodetic measurements along the San Andreas Fault in California. He noted the continuous slippage at a rate of 2 cm in 18 months in the vicinity of Hollister, and strain of the order of one to three inches in ten years along the San Andreas Fault.

S. Miyamura (*Japan*) reported on the results of repeated precise leveling in Japan. He showed examples of settling in coal mining and natural gas producing areas, and indicated considerable correlation between geological conditions and level changes.

A report giving some preliminary observations in movements associated with the recent Chilean earthquake was given by *C. Lomnitz* (*Chile*). He made some comparisons with the earthquakes of 1835 and 1939.

Y. A. Mercheriakov (*USSR*) read a report recommending the establishment of a Commission of the Union to coordinate studies of recent crustal movements. Such a Commission is to be established.

Twelfth General Assembly

International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

METEOROLOGY AND ATMOSPHERIC PHYSICS

General

In accord with its primary aim of promoting research and theoretical studies concerning the atmosphere, and in encouraging cross-disciplinary collaboration on the scientific problems of the atmosphere, the International Association of Meteorology and Atmospheric Physics took several steps at the XIIth General Assembly of the IUGG that are intended to continue and strengthen the organizational framework within which the scientific activities of the Association are conducted.

ELECTION OF OFFICERS

The new officers elected for the triennium 1960–63 are:

President: Horace R. Byers (USA)
Vice Presidents: A. M. Oboukhoff (USSR)
R. C. Sutcliffe (Gt. Britain)
Secretary: W. L. Godson (Canada)
Executive Committee Members: R. V. Garcia (Argentina); M. Koncek (Czechoslovakia), S. Syono (Japan).

COMMISSIONS

One of the most effective mechanisms by which the Association serves the scientific community is through the Commissions of the Association. Provided with sufficient funds for administration, and focussing attention on a special subject, each of the Commissions brings together relatively small groups of active, creative specialists. The three present Commissions and their continuing Presidents are:

Atmospheric Radiation: F. Müller (Germany)
Atmospheric Ozone: K. R. Ramanathon (India)
Atmospheric Chemistry and Radiation: W. Bleeker (The Netherlands)

The following two new Commissions were established:

(1) *Dynamic Meteorology*: Those appointed to this Commission are: B. Bolin (Sweden); A. Eliassen (Norway); K. Hinkelmann (Germany); J. Van Isacker (Belgium); E. Knighting (Great Britain); A. S. Monin (USSR); N. Phillips (USA); C. H. B. Priestley (Australia); P. Queney (France); and S. Syono (Japan). Dr. Bolin was asked to serve as convenor to organize the activities of the commission and to arrange for the election of a President and a Secretary.

(2) *Meteorology of the Upper Atmosphere*: During previous years, a joint Commission had been maintained in collaboration with the International Association of Geomagnetism and Aeronomy. It now seemed desirable to establish a separate Commission and the following members were appointed: A. Belmont (USA); M. Bossolasco (Italy); A. Ehmert (W. Germany); W. Godson (Canada); K. Ramanathan (India); J. B. Gregory (New Zealand); W. Kellogg (USA): R. Murgatroyd (Great Britain); E. Vassy (France). Dr. Kellogg has since been elected President of this Commission.

COMMITTEES

Committee on Ocean-Atmosphere Interactions.

In response to expressions of concern that sufficient attention has not been given to the problems concerned with the interaction of the ocean and the atmosphere in the forthcoming Indian Ocean Expedition, an *ad hoc* Committee on Ocean-Atmosphere Interactions was appointed, consisting of H. Charnock (Italy) and G. E. R. Deacon (Great Britain), with the intention that Corresponding Members would soon be appointed from Australia, Great Britain,

France, Federal Republic of Germany, India, Japan, Pakistan, South Africa, USA, and USSR.

Committee on Meteorological Data for Research. In continuation of its keen interest in the activities of the IGY, the Association considered at some length the most effective means of making available meteorological data for research purposes. Special emphasis was given to the needs of individual research workers who do not have ready access to data processing systems. In view of the importance of this problem, a special Committee on Meteorological Data for Research was appointed, consisting of the Secretary of the Association, W. L. Godson (Canada) as Chairman and the Presidents of the five Commissions as members.

Memberships on Other Committees

Much attention was devoted, quite properly, to the interdisciplinary activities of the Association. With the dissolution of the ICSU Joint Commission on Radiometeorology, an *Inter-Union Committee on Radiometeorology* has been established, with URSI as the Parent Union. The Association nominated B. R. Bean (USA), J. S. Marshall (Canada), A. M. Oboukhov (USSR), P. A. Sheppard (Great Britain), P. Misme (France), and Y. Ogura (Japan) for membership on this Committee.

R. Scherhag (Germany), F. Link (Czechoslovakia), and Dr. B. Haurwitz (USA) were appointed to the *Inter-Union Committee on Solar Terrestrial Relationships*. Dr. Haurwitz will represent IAMAP on the *Joint Committee on Lunar Variations* for which IAGA is the Parent Association.

A joint symposium with the Association of Scientific Hydrology was held at the General Assembly and G. Benton (USA), T. Bergeron (Sweden), A. Jakhelln (Norway), A. K. Khrgian (USSR), R. Linsley (USA), and J. Lugeon (Switzerland) were asked to serve on a joint *Committee on Precipitation* (with IASH).

W. Swinbank (Australia), M. Budyko (USSR), J. Newmann (Israel), and L. Ramdas (India) were appointed to serve on a joint *Committee on Evaporation* (with IASH and IAPO).

Proposed Symposia

The vigor of the Association's program can be seen from the fact that a Symposium on Radiation is planned for Vienna in 1961, and another Symposium, on Ozone, in Arosa also in 1961. Plans were laid tentatively, for a symposium jointly with the International Union of Applied and Theoretical Mechanics on the basic theories of turbulence and their application to meteorological problems. This is to be held in France in 1961. A steering committee consisting of F. Frenkiel (USA), A. M. Oboukhov (USSR), and O. G. Sutton (Great Britain) was appointed to work out plans for this meeting. The Association will cooperate with the WMO in a Symposium on Climatic Change, to be held in Rome, in 1961, and with the Australian Academy of Science on a Cloud Physics Symposium to be held in Australia, also in 1961.

Some consideration is being given to a Symposium on Atmospheric Chemistry in 1962.

With respect to the proposed plans for an international cooperative effort in geophysics during the expected sunspot minimum in 1964–65, the Association urged that the World Meteorological Organization take the lead in planning the collection of such special meteorological observations as may be deemed necessary.

Sessional Meetings

Meteorological Uses of Rockets and Artificial Satellites

W. H. Alfuth, (USA); Climatology and Missile Problems.

This was a review of the atmospheric (aerodynamic) effects on a missile during its boosted flight and re-entry, with emphasis on the latter.

W. G. Stroud, (USA); Operations and Results of the Tiros I Meteorological Satellite.

The booster was a Thor Able, placing Tiros I on a near circular orbit (per. 430 mi, ap. 460 mi). The satellite was solar powered, and had two transmitters and a command receiver. A summary of the optical characteristics of the double TV camera system is:

	Wide	*Narrow*
Field of View	104°	12.7°
Aperture	f/1.8	f/1.5
Exposure	1.5 m. sec.	1.5 m. sec.
½″ Area Target	500 lines	500 lines
Areas on ground when looking in vertical	(750 mi.)²	(65 mi.)²
Shadows of Grey	5–6	5–6
Peak Spectral Sensitivity of Both Systems at 0.7 μ		

The pictures obtained were snapshots, which were retained on the TV tube for about 10 seconds while they were read off and either stored on tape or transmitted directly.

Tiros I was launched on April 1, 1960; by June 17 it began to misbehave, and by the end of June it gave up. However, it had gained about 24,000 pictures, of which about 16,000 gave some meteorological information.

The speaker gave examples of the pictures, demonstrating the resolution and quality. The resolution is about 2 mi for the wide angle camera and 0.1 mi for the narrow angle camera. One of the examples shown was a pass through central Africa, across the Mediterranian and over the Caspian Sea into the U.S.S.R.

S. Fritz (USA); Meteorological Uses of Satellites.

Showing a number of examples of large storms in both the northern and southern hemispheres, Fritz pointed to a number of unusual features that are not detected on the normal weather map, e.g. multiple frontal systems to the south of a well developed low pressure system over the Pacific, sharp variations between stratiform and cumuliform regions, et al. Detailed analysis of a major storm over the North Atlantic brought out the complexity of such a cloud system. Another curious example was that of an almost perfectly square, isolated cloud over Oklahoma or Texas which, as it turned out, contained several thunderstorms and at least one tornado.

The following points were brought out in the discussion that followed. (1) One cannot very well obtain total cloud cover from Tiros I owing to the poor orientation at most points, and to the incomplete areal coverage. (2) The absolute intensities of the cloud illumination are not known, owing to doubtful calibration. (3) The time from picture taking to photographic presentation for the direct readout is about 15 minutes, and even for the stored data it is generally faster than the normal aerological communications channels. (4) The cloud information from Tiros I has been used operationally in a limited way, and has, in fact, helped in the locating of several systems over the oceans—systems that could not be followed very well with the existing network. The real value of cloud pictures alone was discussed, and it was expressed that, in addition to quanitatitve cloud pictures, more quantitative measurements of the radiation balance would greatly add to the value of the future meteorological satellites that are being planned by the United States.

V. Suomi, (USA); Long Wave Radiation as Measured from Explorer VII.

The experiment which Suomi described was designed to measure, from a satellite, the solar flux that enters the atmosphere, the part that is scattered back from the Earth, and the infrared radiation leaving the Earth and atmosphere. By measuring these various fluxes one can deduce the heat budget of the portion of the Earth and atmosphere within the field of view of the satellite. On Explorer VII there are three hemispheres mounted on mirrors—a black, a white, and gold—that represent balls isolated in space and responding to the radiation environment. As the satellite travels on its orbit it measures the effective heat budget of a rather wide area, a circle about 500 km in diameter at perigee, and over 1000 km at apogee. The patterns of high and low heat loss in the atmosphere were shown to bear a rather close resemblance to the synoptic patterns on the 500 mb chart, and in one case it was shown that the cloud pattern seen in a Tiros I picture of a well developed low over the Gulf of Alaska agreed quite well with the radiation pattern seen by Explorer XII.

The data from this experiment are digitalized on board and sent continously on the 20 Mc carrier. These transmissions are then recorded at a number of stations, and the tapes are sent to the University of Wisconsin for decoding and processing; this procedure is now automated with an IBM 704. It was noted by Suomi that his maps of the heat balance of the northern hemisphere were complete except for the area of Asia, and he expressed the hope that someone from this area might be willing to help by providing the University of Wisconsin with some Explorer 7 recordings.

John H. Conover, (USA); Cloud Patterns as Seen from Altitudes of 150 to 1350 KM.

In order to introduce the subject and put his audience into the right frame of mind, the speaker showed the famous movies taken

from an Atlas rocket flying high above the South Atlantic, and then showed how the cloud patterns at some places relate to the lower level flow and at other places to the higher levels. The same was then shown to be true for some Tiros I pictures, where the jet stream could be detected, over Egypt and Arabia, as a band of cirrus. The diverging flow at lower levels could be seen over the ocean to the south of a low pressure system in the Gulf of Alaska, where the air flow over Florida could be seen as streaks in the cumulus patterns as the air moved inland, etc. Generally, cloud types cannot be identified directly from the wide angle Tiros pictures, but inferences can be made from the brightness and larger scale structure (with features larger than about 10 km). Finally, some cloud patterns have been seen which have not been identified before, and which require physical explanation, such as more or less straight rifts extending for 1000 km, doughnut-shaped clouds, elongated cumulus agglomerations in regular patterns, *et al.*

L. D. Kaplan (USA); The Practicability of Stratospheric Sounding from Satellites.

By looking at the upward radiation in seven different wave lengths in the CO_2 band at around 15μ, with spectral bandwidths of the order of 5 cm^{-1}, one could, in principle, determine temperatures at seven different levels, e.g. 1000, 700, 400, 300, 200, 100, 50 mb. Actually, in performing such a computation to determine temperatures from spectral observations there is no explicit solution, it being a question of an inversion of a matrix. The approach used is iterative, starting with a model temperature distribution. There was a discussion of the errors involved in such a determination when systematic errors exist in the flux measurement. On the whole, the idea looks quite promising for satellite use.

Communication from J. T. Houghton; read by Alan W. Brewer (Gr. Britain).

If one could look at just one wave length at a time, one could then see the radiation from a limited layer (like a Chapman layer), but over a wider band one would see contributions from several regions corresponding to different absorption coefficients, and could not sort them out. "It would be like taking scrambled eggs and trying to deduce the shape of the eggs." If one narrows the spectral band enough to see only one part of one absorption line, then one does not have enough radiation to work with. The alternative suggested by Houghton involves using an interference filter (interferometer) with the spacing between orders of the filter being made equal to the spacing between lines in the band (the R band of CO_2, from 670 to 690 cm^{-1} being used in the example). In this way a number of lines with equal absorption all contribute, making enough energy available to the detector.

Climatology

Although the session of July 29 was labeled climatology, only three of the papers presented were within the scope of traditional climatology.

The contribution by *P. Karapiperis (Greece)* dealt with the nearly parallel temperature trends at Athens and Rome for the last century (correlation coefficient of annual values, $r = +0.97$). Marked rises were noted since the last century, and they were of the same order of magnitude as those observed in the eastern United States. The suggestion that the changes were caused by shifts in the general circulation found emphasis in the discussion, which brought out that in Innsbruck, for example, the Foehn winds had decreased very significantly since the second decade of the 20th century. *E. Rosini (Italy)* stressed the value of sequential statistical analysis for the study of trends.

An interesting example of a southern slope climate in the High Jatra was brought out by *M. Koncek (Czechoslovakia)*. The afternoon differences during summer and winter between valley, slope, and summit are very pronounced, and are caused by completely different convective states. The elevation difference of 1900 meters makes this a particularly good, and new, case history of a well-known phenomenon.

Three papers dealt with microclimatic problems. *A. E. Valmari (Finland)* presented charts of frost danger for Finland, the northernmost country where wheat, oats, rye, and barley are grown. The favorable influence of the Gulf of Bothnia is felt for 10 to 15 miles inland. Similarly, in the lake region the water surfaces exercise a mitigating influence. Experiments with SO_2 smoke reduced outgoing radiation by

only 10 per cent. Sprinkling has been used, but is too expensive. The canopy of trees has been used to reduce outgoing radiation by 50 per cent, and the shelter, in spite of reduction of illumination, has given higher crop yields. The protection of birch trees has also been used to start young spruce trees, which are particularly sensitive to frost damage.

Dzerdzeevskii and Rauner (*USSR*) gave considerable detail on the influence of forests on the heat balance near Moscow. Among the interesting results is the determination of the roughness parameter (Z_0 = 2 meters), which is about 1/10 the height of the trees. In the energy balance of the deciduous forest, evapo-transpiration is the largest element; at the beginning of the vegetative period this is about 0.6 cal/cm²/min, at the time of the fall of leaves it is 0.35, and after the fall of leaves it is 0.1.

Dalrymple (*USA*) gave some preliminary results of micrometeorological observations at the South Pole and at Little America, where, the main phenomena are, obviously, the extraordinary shallow inversions. At Little America the greatest inversion was 14°C, between 5 cm and 2 meters height, and six weeks after sunset; up to 10°C inversions were noted, even when the sun was well above the horizon, as surface wind speeds were less than 10 m/sec in 87 per cent of the cases. At the South Pole the surface inversion averaged 21°C; it depends primarily on wind speeds. In the range from five to 15 m/sec the surface temperatures increase by about one degree C for each meter per second increase in wind speed. The low-level wind profiles are very similar at the South Pole and at Little America; the profiles are logarithmic from the surface to four meters, and commonly up to eight meters in height. The micrometeorological conditions are governed by the complex Antarctic circulation. Storms from the low-pressure belt penetrate far inland, and low-pressure systems and fronts even occasionally cross the Pole.

Bugayev (*USSR*) draws some rather remarkable conclusions from an analysis of the basic temperature and heat-flow structure of the Antarctic. Certainly the Antarctic is an area of a heat loss that is greater than the heat loss in the northern hemisphere; however, the cold layers are very shallow. Moreover, topography causes adiabatic heating at the edges of the continent. The heat flux in July at 70°S latitude is calculated at 13 cal/cm²/day, compared to 10 in similar northern latitudes in January. The area encompassed by the zero degree (centigrade) isotherm in July in the southern hemisphere is smaller than that within the same isotherm during January in the northern hemisphere. Hence, it is concluded that the Antarctic, contrary to the prevailing opinion, does not influence the climate of the southern hemisphere; rather the Antarctic ice cap exists because the southern hemisphere with its preponderance of water is, a priori, the colder of the two.

Two papers dealt with tropical meteorology. *C. S. Ramage* (*USA*) pointed out, again, the fallacy of transferring middle latitude concepts into synoptic analyses and prognoses in the tropics. In particular, the geostrophic wind approximation fails. For example, in the 500-mb level at 30° latitude, 30 per cent of the winds deviate from the geostrophic, and at 10° latitude even 83 per cent do so. Ramage suggests for low-latitude forecasts the use of actual winds in forecast models to estimate vorticity advection. Combinations of persistence and climatological values, combined in regression equations, gave good results for short-range forecasts at the 30,000-foot level in Hawaii.

Expeditionary wind and temperature observations led *S. P. Khromov* (*USSR*) to postulate various types of wind and weather patterns in the equatorial zone, now too loosely called the 'intertropical convergence zone.' Several major patterns emerge. Some show sharp frontal zones with rapid transition between the two trades. In some cases the momentum conservation will carry the trade wind without change of direction into the other hemisphere, the coriolis parameter being too weak, near the equator, to modify the direction. A clash on the two trade winds resulting in frontal characteristics will occur. In other instances, weak west to east pressure gradients at the equator will lead to separation of the trades by a zone of west winds, two to four degrees of latitude wide. Differences of ½ millibar in the surface pressures may lead to such westerlies with speeds up to 10 m/sec. Other patterns of winds in the equatorial zone are conceivable, and better observations might lead to a considerable revision of present concepts of equatorial circulation.

Structure of the Atmosphere

Two sessions were held on August 1. The topics treated ranged broadly, from micrometeorological aspects within the first few meters of the atmosphere, to the problems of the grand centers of action, and the general circulation of the troposphere and stratosphere.

Monin (*USSR*) and collaborators, *V. M. Bovsheverov, L. R. Zwang,* and *A. S. Gurwich* (*USSR*) investigated the lowest two meters with a very sensitive ultra-sonic anemometer and resistance thermometer. The linear response of the ultra-sonic thermometer was particularly well-suited to turbulence and heat flux measurements. The main heat flux was found to be a consequence of turbulent eddies having a frequency from 0.1 to 1.0 cycle a second.

N. S. Bibilashvili (*USSR*) described numerous determinations of vertical velocities in cumulus congestus clouds, with the help of equilibrium balloons equipped with radar targets. To offset the influence of wetting in clouds, a free lift of five grams was used. The vertical velocities within the clouds were compared with calculations based on the atmospheric stratification. The vertical velocity distribution within the clouds was correlated roughly with droplet size.

J. Neumann (*Israel*) dealt with the variation of wind with height in the atmosphere in the special case of linearly increasing eddy viscosity.

S. Syono (*Japan*) treated some problems of typhoon dynamics. He developed a numerical model considering a circular symmetrical vortex in a latently unstable atmosphere, and made use of the primitive equations in pressure coordinates, considering none layers each of 100 mb thickness, from 1000 up to 100 mb.

W. L. Godson (*Canada*) described a large number of high level temperature-time graphs that showed the dramatic transitions in stratospheric temperatures in the Arctic and Antarctic regions. He displayed numerous cases of the explosive warming that may precede almost any period during Northern winter, but in the Southern Hemisphere seems always to be delayed until the spring months. A lively and lengthy discussion followed, because of the probable relationships of these temperature changes to ozone variation and the general circulation of the troposphere.

R. G. Fleagle (*USA*) completed the morning session with a highly significant contribution. A penetrating analysis was made attempting to estimate the effects of external heating on large scale disturbances, particularly off the east coast of continents in winter, where cyclogenesis ensues. A linearized two-layer model was employed, revealing that heating due to condensation in the middle troposphere may lead to both increasing instability and a shift in maximum instability from a wave length of 5000 to one of 3000 km. This attack shall be welcomed in seeking to overcome present deficiencies in numerical prediction models when applied in wintertime to east coast situations.

The afternoon session was devoted principally to jet streams and related phenomena. *E. R. Reiter* (*Austria*) presented some very detailed analyses of the mesostructure of the temperature and wind fields in and around jet cores. He posed numerous challenges to the theoretician for explanation of observed structure.

D. P. McIntyre (*Canada*) expanded upon his earlier studies by associating the annual and seasonal variations in jet streams with 500-mb. temperatures and features of the four-air mass, three-jet stream models.

M. A. Petrozyants (*USSR*) and his colleagues presented a paper on the influence of Central Asian mountain systems on the region flow patterns of the general circulation, with particular reference to the jet stream. He indicated that the influence of the mountains extends at least to 16 km. He showed also how the jet stream is fractured into streams lying to the north and south of the ranges.

G. V. Gruza (*USSR*) gave a paper on the macroturbulent exchange in the atmosphere and zonal peculiarities of the circulation. A tremendous amount of computational work was described, which gave numerical values for zonal velocities, kinetic energies, meridional movements (as well as the meridional transport of heat and momentum and divergence of these quantities), and the energy exchange between mean and 'pulsating' movements. This paper will be studied with interest by the many meteorologists who deal with numerical characterizations of the general circulation.

F. Defant (*Austria*) described extensive synoptic studies of the upper air over the Northern Hemisphere using all available radiosonde data. He again demonstrated world-wide character of

the threefold division of the tropopause–polar, mid-latitude, and tropical–with two main breaks or discontinuities separating the three distinct types. Many aspects of synoptic meteorology were tied in with his work, including transitory phases of the general circulation like blocking phenomena.

L. S. Gandin (*USSR*) reported on an objective procedure for analyzing meteorological fields. Various problems of objective analysis were brought to light and the solution by the proposed method indicated that quite successful results may be achieved quickly with the help of an electronic computer.

L. Alpert (*USA*) described the cloud formations that characterize nuclear explosions of varying strength. The rate of rise, as well as the development of the mushroom cloud, was found to be associated with the magnitude of the explosion.

Joint Session on Atmospheric Electricity

A joint session with the International Association of Geomagnetism and Aeronomy was held on August 1.

Eight papers were presented on the subject of Atmospheric Electricity. For the most part the papers dealt with refinements of the work carried on by the Carnegie Institution of Washington during the period 1920 to 1940.

Symposia

Symposium: Low Water Supply and Periods of Drought

Reported under Scientific Hydrology.

Symposium: on Dynamical Processes in the Atmosphere

Opening remarks by the Chairman; *Dr. Philip D. Thompson.*

As indicated by its title, this symposium will not deal with all aspects of meteorology, or even with all aspects of dynamical or theoretical meteorology. It will deal almost exclusively with dynamical processes associated primarily with the large-scale motions of the atmosphere, except in instances where its small-scale motions have a decisive effect on the large-scale motions. This field was chosen by Professor van Mieghem and Doctor Sutcliffe as one in which progress has been relatively rapid over the past five or ten years. It is, in fact, true that our ideas about the role of the large-scale motions have changed markedly since 1948, and that many new concepts have been introduced. To a great extent, of course, this is due to more complete knowledge of the atmosphere's actual behavior. But it is also true that much of our progress can be attributed to better and more complete physical interpretation of what we have observed. In this respect, the development of theory and methodology has been crucial in the development of this entire field.

The most striking and fruitful developments in this field, as in all fields, are those that open new approaches, for they state new viewpoints and lay down new methods. Among the most important developments are the following:

(1) The application of numerical methods and high speed computing techniques to the analysis of simple mathematical idealizations of the atmosphere. These methods were developed originally for short-range weather prediction, and were based on dynamical principles, but have proved enormously valuable in the study of the general dynamical processes of the atmosphere. The earliest example of this approach, of course, was presented by Phillips in his now classical paper of 1956.

(2) The study of simple laboratory analogues of the atmosphere, in which external influences are known or rigidly controlled. It is true, of course, that the behavior of the atmosphere can be simulated in only certain limited respects. Nevertheless, it is a matter of observation that much of the large-scale behavior of the atmosphere is reproduced in very simple and well-defined fluid systems. This is encouraging, if only because the theoretical and mathematical analysis of atmospheric problems is probably less formidable than we supposed. Otherwise, it may turn out that the most important external influences on the atmosphere are not as complicated as one might imagine—if he knew nothing of the behavior of simpler fluid systems.

(3) Curiously enough, the assurance that some problems could be solved by machines and numerical methods has evidently encouraged the purely analytical approach to many meteorological problems. In some way, the development of numerical methods seems to have removed some intellectual bloc or inhibition, so that we are no longer afraid of heuristic approaches to very complicated problems.

Examples of these three developments appear in the first session of this symposium. The second session will emphasize the first new approach, that is, the application of numerical methods. The third will stress the effects of heat sources, horizontal momentum transport, and vertical flux of momentum by small-scale motions in the atmosphere's turbulent boundary layer. The last session will deal with the dynamics of various typical flow structures.

To conclude, I think we stand at the brink of a truly historical development in meteorology. Today, we posses the basic ingredients of a theory of the atmosphere's general circulation and of the evolution of climate. Our problem now is to assemble the essential parts of the mechanism—parts that we now recognize as essential—and to synthesize a theory that faithfully describes the essential meteorological behavior of the atmosphere. You, yourselves, can judge how close we stand.

J. Charney (USA); On the Propagation of Planetary Wave Energy from the Lower to the Upper Part of the Atmosphere.

In considering the upward propagation of the energy of planetary waves in the atmosphere, one might expect that propagation with constant energy density would occur. If this were to happen, a system with velocities of 10 m/s at 1000 mb would, if converted to heat, at the 100 km level, result in a temperature rise of 10^8 degrees Celsius, giving a corona to the Earth. The problem to be solved is: why this doesn't happen?

By solving for the propagation of atmospheric waves under geostrophic control, a propagation equation is obtained, in which

$$\frac{d^2R}{d\zeta^2} + \mu^2 R = 0$$

Here, R is a function of the static stability and the geostrophic wind, ζ is a non-dimensional vertical coordinate, and μ^2 is related to the refractive index for the wave, depending on the distribution of the mean zonal velocity, u, the rotation of the Earth, and the wave length of the disturbance. This equation was applied to high atmospheric data recently compiled by Murgatroyd. For summer conditions, a trapping of the upward-directed waves occurs under a deep layer of high-level easterlies, such that further upward propagation does not occur. Trapping is also indicated at approximately the same level (20-30 km) in winter. However, in spring and fall, some possibility of continued upward propagation to levels much higher than these is indicated by Murgatroyd data, but is not indicated by other data produced by Kochanski.

The trapping of the waves at 20-30 km is most efficient for disturbances having wave lengths under 6000 km. Atmospheric waves of greater length are generated by terrain effects and by differential heating. For these long waves, some upward escape of energy through the trapping layer at 20-30 km is considered possible.

Discussion: *A. M. Oboukhov* (*USSR*) asked why one might expect that energy density should be conserved as waves are propagated vertically. *Charney* replied that according to his results one should not expect it, but that earlier studies of simpler types of wave propagation might lead one to believe that the conservation of energy density is a universal principle.

A. Eliassen described his studies of wave refraction in the upper atmosphere, and mentioned results which showed that around 10 per cent of the original wave energy might escape from a 'trapping' layer. This would still be enough to produce a corona. It was agreed that no study of vertical wave propagation had yet resolved all of the problems and apparent paradoxes.

S. A. Mashkovich (USSR): Some Problems of the Large-Scale Atmospheric Process Studies by the Methods of Hydrodynamics.

Two models are used in the investigation of the problem of atmospheric macro-processes. The first is a model of the zonal circulation. In this case the initial equations are (a) The heat influx equation, (b) The radiative energy transfer equation, (c) The heat conduction equation for the soil, and (d) The equation of hydrostatics. The problem is solved at the arbitrary initial distribution of the meteorological elements and the given variation of the solar enegry influx. The system of equations is solved by numerical methods using the high-speed computer. The results of the computations have made it possible to estimate the effect of the initial atmospheric state on the subsequent

development of the zonal motion, and to formulate some conclusions as to the character of the large-scale thermal transformation. The annual variations of the zonal temperature and of the zonal circulation were computed and are in good agreement with the actual data.

The second model relating to studies of the general circulation is based on use of the vorticity equation, the heat influx equation for the atmosphere and the under-lying surface, the equation for moisture, and the equation for hydro-statics. Quasi-solenoidal motion, distribution of continents and oceans, is taken into account and the heat influx from the sun is given. The system of non-linear equations is solved for the case of the arbitrary initial distribution of the meteorological elements, and the solution is searched, by numerical methods for the 'five-layer' version of the atmosphere. The results of computations led to formulation of some conclusions on the role of different factors in the development of the large-scale atmospheric process. The wave stability in the baroclinic current was also investigated, and, in particular, the dependence of the disturbance stability on the speed profile in the main current and on temperature stratification was considered.

J. Smagorinsky (USA): General Circulation Experiments with the Primitive Equations, as Functions of the Parameters.

Numerical integrations of a baroclinic, primitive equation model have been made for the study of the dynamics of the general circulation. The vertical structure permits use, as dependent variables, of the wind at two internal levels and a single temperature, with the static stability as a parameter. The incoming radiation is a function of latitude only, and the outgoing radiation follows the Boltzmann law. With the requirement of radiative equilibrium, the domain mean temperature is specified as a parameter. The kinematics are those of a fluid bounded by smooth zonal walls at the equator, and at approximately 64° latitude, on a sphere with a constant geopotential surface. The dissipative sinks are provided by: (a) surface stresses proportional—through the drag coefficient—to the square of the surface wind, which is suitably extrapolated from above, (b) internal convective stresses proportional to the vertical wind shear, and (c) laternal diffusion of momentum and heat, through an exchange coefficient which depends on the rates of strain as deduced from a similarity theory in which a horizontal length scale enters as the governing parameter.

For a given specification of the parameters, integrations to 60 days have been made from initial conditions where random temperature disturbances have been superimposed on a zonally symmetric current that is baroclinically unstable, according to linear theory. The results of this basic experiment (presented elsewhere; manuscript in preparation) not only display the scale selective character of baroclinic instability, which was already shown numerically by Phillips, but also predicts the index cycle, in this case with a period of 12 days. The resulting mean zonal velocity is quasi-geostrophic to within 5 per cent, being super-geostrophic north of the angular momentum maximum and subgeostrophic to the south. The total zonal angular momentum remains constant to within ± 2 per cent, irrespective of the phase of the index cycle. The northward transport is accomplished mainly by large-scale eddies, whereas the internal vertical flux is predominantly a transfer of the Earth's angular momentum by the meridional circulation, being upward in low latitudes and downward in middle latitudes.

The northward heat transport is shown to be primarily accomplished in low latitudes by the Hadley circulation, and in mid-latitudes by the large-scale horizontal eddies. That the Ferrel circulation works against the large-scale horizontal eddies is evident from calculations of the potential-kinetic energy transformations by the mean zonal and mean meridional circulations. Comparison of these results with calculations of the momentum and heat flux from observed data by Starr-White, Mintz, Palmen, and Priestley shows surprisingly good agreement.

A subsequent series of experiments was performed in order to determine the sensitivity of the results to the empirically prescribed parameters, and also to study the general circulation of the model for physical conditions that differ from those of the basic experiment. Variation of the surface drag coefficient by as much as eight times results in practically no change in the surface stress, and hence in the latitudinal distribution and magnitude of the exchange in angular momentum between the atmosphere

and the Earth's surface. This must mean that the heating gradient (which determines the intensity of large-scale eddy northward heat flux and hence the flux of angular momentum) ultimately determines the amount of angular momentum exchanged with the ground. Depending on the drag coefficient the surface wind adjusts to meet this requirement.

A removal of the short wave radiation yields an e^{-1} total energy decay of 20 days. If, in addition, one suppresses the long wave sink the decay is only 40 days. These decay periods are considerably longer than earlier estimates, because of the availability of potential energy.

Doubling the gradient of the incoming radiation increases the ratio of the available potential energy of perturbations to that of the zonal mean with a shorter period index-cycle—both the increased gradient and the available potential energy being necessary to meet the increased demand of northward heat transfer. The wave number of maximum instability is reduced from 5 to 6 to a value of 4 to 5, corresponding to the greater meridional temperature gradient.

The simulation, through the static stability, of the release of latent heat shows the typical contraction of scale and amplification of upward vertical motions.

Alan J. Faller (*USA*): *Zonally-Asymmetrical Heating Functions Applied to a Laboratory Analogue of the General Circulation.*

Experimental laboratory models have shown promise as an approach to the study of planetary fluid circulations. Their advantage lies in the use of an actual fluid substance, and the production of a real fluid circulation with no approximations to the equations of motion. Time and space scales may be made conveniently small, and boundary conditions may be readily altered to study a wide variety of conditions.

The specific results reported here are part of an exploratory study with a laboratory model of the general circulation. The apparatus consisted basically of a tank, two-meters in diameter, with water 10 cm deep, rotated slowly about a vertical axis in the center. Circulation was produced by heating beneath the rim. The heat sink was provided either by cooling from beneath in the central region, or by allowing the fluid to warm up slowly and continuously; in the latter case, the heat sink was the heat capacity of the fluid, and was distributed uniformly throughout the volume. The circulation was dependent only upon the gradients of density, and was not altered significantly by the rise of the mean temperature. Observations of the circulation were made by photographs of particles on the free surface. The thermal structure was obtained by 15 resistance-wire thermometers that gave the zonal average of temperatures at three depths and five radii. For a wide range of heating rates the model was shown to exhibit a circulation similar in many respects to that of the Earth's atmosphere, with the notable exception that the mechanical exchange of kinetic energy between the mean flow and the eddy motions was found to be zero average for each experiment. This fact may be related to the absence of a radial (latitudinal) variation of the vertical component of rotation, which, on theoretical grounds, is generally considered to be a primary factor for this particular energy transformation.

On the other hand, the introduction of zonal asymmetries in the heating distribution, with either two or three heated sectors, was shown to produce the following significant changes: (1) with the asymmetries there was found to be a significant transfer of kinetic energy from wave numbers 5 and 6 to wave numbers 2 and 3, and then to the zonal flow; a stronger mean zonal flow was observed; (2) a pattern of mean troughs and ridges was found, which bore the same relation to the heated sectors as does the atmospheric flow pattern with respect to the oceans in the winter season; (3) an 'index-cycle' oscillation was produced, and the period of the oscillation was related to the speed of movement of the short-wave troughs through the mean long-wave pattern produced by the asymmetries.

One must admit to many differences when the nature of the fluid and the boundary conditions are compared with those for the Earth's atmosphere. However, the model is dynamically similar in several important respects, and the results suggest that such models should be given further serious consideration.

Discussion:

R. Hide emphasized that Dr. Faller had ignored some effects in his dimensional analysis of the basic equations describing his experiment, and stated that the behavior of the fluid

is actually a function of a second nondimensional parameter. Dr. Hide then described some of his own results, indicating that the flow could assume any of three characteristic forms, depending on the value of the latter parameter. In reply, Dr. Faller pointed out that Hide's experiments were carried out in a deep and relatively narrow annulus, and that the existence of boundary layers along the sides of the annulus cast some doubt on the relevance of Hide's conclusions. The question remained unresolved.

A. M. Oboukhov (USSR): Choice of an Optimum Model of the Baroclinic Atmosphere With a Given Number of Parameters, On the Basis of Statistical Analysis.

The author first considered the problem of expanding any function of elevation as a linear combination of 'natural' orthogonal functions, which have the orthogonality properties of analytic functions. The natural orthogonal functions are determined by minimizing the standard error of representation, and are shown to be related to the variance and covariance of the function to be represented. These results were applied to the vertical representation of interdiurnal pressure changes. The first of the 'natural' orthogonal functions is a single-signed function, varying monotonically over most of the range of elevation; the second has a single zero located in mid-troposphere; the third has two zeros; the fourth has three zeros. The general character of the functions does not change markedly from one season to another, but may vary widely from day to day.

The results of calculations from observations showed that the first two orthogonal functions alone describe the vertical distribution of pressure change, with a standard error of about 5 per cent of the standard deviation. The first three functions describe the vertical distribution, with a standard error of about 2 per cent of the standard deviation.

Discussion:

Dr. Bolin inquired about the statistical stability of the 'natural' orthogonal functions, and asked whether or not Professor Oboukhov had studied the conditions under which the optimum representation remained the same from one time to the next. He pointed out that the answer to this question depends on the dynamical properties of the atmosphere. Professor Obukhov replied that he had not yet studied the dynamical equations as applied to 'natural' orthogonal representations.

Professor Charney stated that he thought the stability of such statistics is due to the stability of rotating fluids, that is, they tend toward a state of barotropic motion.

E. Knighting (Great Britain): Some Computations of the Profile of Vertical Velocity.

It is well-known that vertical velocities cannot be measured accurately in the atmosphere, except with special equipment and at a few isolated points, and that so far it has not been possible to make routine measurements to aid in the problem of synoptic forecasting. The baroclinic models that have been used to make numerical forecasts have usually assumed an analytic form for the vertical variation of the rate of change of pressure on a moving air parcel; in particular, the two parameter models have assumed a parabolic distribution. The investigation was designed to inquire into the vertical distribution of the rate of change of pressure, dp/dt, using data from more than two levels in the atmosphere.

Numerical predictions have been made in which the horizontal velocity field has been obtained from the contour height field through the geostrophic relation. These computations have been successful in predicting the motion of synoptic features; the associated computed vertical velocities at mid-tropospheric level agree in sign, and often in magnitude, with those that would be inferred from observations of weather and development. It is reasonable to suppose that the main features of the profile of vertical velocity are reasonably estimated by using the geostrophic wind as an approximation to the wind in the computation of advection and vorticity.

With the geostrophic assumption, the vorticity and thermodynamic equations yield a diagnostic equation for $\tilde{\omega}(=dp/dt)$, which is elliptic in character; the forcing term depends upon the horizontal and vertical derivatives of the contour heights, and can be approximated by using finite-difference methods. The upper air charts were analysed at each 100 mb interval between 1000 and 200 mb, and the diagnostic equation solved to give values of $\tilde{\omega}$ at each of the inter-

mediate levels at 480 points of a horizontal mesh. It was assumed that $\tilde{\omega}$ is vanishingly small at 1000 and 200 mb, and vanishes at the boundaries of the region. The results are given at the points of an inner mesh of 192 points, where the lateral boundary assumptions should not lead to gross errors.

The most striking result is the consistency in shape of the profiles, so that any feature in a particular profile is discernible in nearby profiles, excepting, of course, in regions where there is a complete change in the vertical velocity structure with the air ascending at one set of grid points and descending at the neighbouring set. Where there was considerable vertical motion, the maximum occurred near the mid-tropospheric level, and the shape of the profiles was approximately parabolic in form. In areas of lesser upward motions there were marked departures from the parabolic form, and occasionally the profiles showed regions in which the sign of $\tilde{\omega}$ changed as pressure decreased; this indicates more than one level of non-divergence associated with air moving vertically in opposite directions, in the same column. The level of non-divergence appeared, in the mean, to be slightly above the mid-level, but for a two-parameter model the assumption of a parabolic variation in the vertical is reasonable.

Discussion:

Dr. Palmer: I am interested in knowing the maximum values of vertical velocity obtained. The vertical velocities ordinarily derived from simple atmospheric models seem too small to accomplish the necessary energy transformations.

Mr. Knighting: The maximum values observed in the situations for which we made calculations were about 35 millibars per hour.

George P. Cressman (USA): A Diagnostic Study Baroclinic Processes.

This study represents an effort to describe some of the atmospheric processes occurring during cases of baroclinic development, as revealed by failures of the barotropic forecasts in cyclogenetic situations. An equation for vertical velocity is applied to atmospheric data at the three levels—850, 500, and 200 mb—in order to determine mid-tropospheric horizontal divergence patterns. The calculation also permits the evaluation of the contributions of vertical advection of momentum by the large-scale vertical motion pattern, and the resulting contribution to flow pattern changes in mid-troposphere.

The divergence calculations are presented in the form of cross-sections running through the regions of maximum error of the barotropic forecasts. During periods of small baroclinic activity, when good accuracy of barotropic forecasts is obtained, the horizontal divergences are small, and there is a single surface of non-divergence located near 500 mbs. As cyclogenesis occurs, a double non-divergent surface is found, with horizontal convergence in mid-troposphere, and with horizontally divergent layers above and below. The area of mid-tropospheric horizontal convergence is, in the situations studied, located in the same place as positive height errors in short-range barotropic forecasts.

The results of the evaluation of vertical momentum advection by the large-scale vertical motions are presented in the form of calculations of the 500 mb height tendency, both with and without the inclusion of this effect. Although the contribution of this term is mostly negligible, a significant addition to the deepening of the 500 mb trough is found in the cyclogenetic situation. The correctness of the magnitudes of the divergence patterns is difficult to verify. However, several independent estimates tend to verify the approximate magnitudes shown.

Some particular atmospheric features associated with the divergence patterns described above are the low level cold push, located under a low, warm, stratosphere, in the rear of the disturbance, and the sub-tropical jet stream. As a consequence of the well-known fact that the cold push is confined to the lowest two-thirds of the atmosphere and is associated with strong descending motions, which decrease in magnitude upward, mid-tropospheric convergence is required from continuity considerations. In front of the disturbance, where upward vertical velocity occurs under a strong subtropical jet stream, the strong vertical shear in the high troposphere requires the maximum ascending motions to be located at relatively high level. Again, in this area, mid-tropospheric convergence is required by continuity. Several well-known

forecasting rules can be related to the above processes.

Discussion:

G. Sutton (*USA*): The cases you have shown bring out a practical problem. When a failure of the forecast model is about to occur, should we refrain from using the numerical prediction, and prepare one by hand, or is there some other solution?

G. P. Cressman (*USA*): It is easier to recognize that a failure is imminent than it is to specify the form of the failure with sufficient accuracy to have any use. I think that the only satisfactory solution will be attained by the use of more complete and accurate atmospheric models.

J. Bjerknes (*USA*): *Mid-Tropospheric Cyclogenesis.*

Although the numerical forecasting based on vorticity advection has achieved encouraging success in predicting the movement of perturbations at the 500 mb level, the 'development' of such systems cannot be expected to be well predictable without full consideration of the non-advective terms in the vorticity equation. The synoptic research to be reported on is concerned with several cases of intensification of a 500 mb maximum of absolute vorticity, and may in due course serve to guide the attempts at further improvement of numerical forecasting of such 'mid-tropospheric cyclogenesis.' The mid-tropospheric cyclogenesis is frequently and typically displayed over the western United States, and represents the most important forecasting problem in that region. Detailed analysis reveals the initial disturbance a short wave trough that forms in the high latitude part of the westerlies, closely downwind from a major stationary upper ridge. The maximum of relative vorticity associated with the short wave trough increases on its way toward lower latitudes, not only by the β-effect but also through the twisting effect. A very sudden growth of relative cyclonic vorticity can thereby result, which easily escapes prediction with present methods.

In order to evaluate the quantitative contribution to the vorticity production supplied by the twisting effect, the three-dimensional field of vertical motion is derived by methods developed at New York University under the dry-adiabatic assumption. This seems to be well justified for the synoptic development under consideration which is very quick, and originates in cloudless air in the upper half of the troposphere. The obtained field of vertical motion, together with that of vorticity, also supplied information about the vertical advection of vorticity. Moreover, as a by-product from the field of vertical motion the field of horizontal divergence is available, so that the divergence term also can be studied in its effect on the development process.

The main conclusion is that the new nucleus of cyclonic vorticity in the upper troposphere arises by the twisting effect, presumably started under lack of geostrophic control, down-wind from the place of strong anticyclonic curvature. Once started, the new shortwave trough shows the usual distribution of pre-trough divergence and post-trough convergence which makes it move a little slower than the air. The vertical advection of vorticity seems to be mainly instrumental in bringing cyclonic vorticity down to lower levels from the upper tropospheric layer of initial development. Within the new perturbation, fast moving air from the upwind jet stream sinks while adjacent slower moving air rises so that a net downward flux of kinetic energy feeds into the mid-tropospheric cyclogenesis. When the same perturbation grows into a 'cut-off upper low', part of its kinetic energy trans forms into potential energy, as seen by the lifting of the cold core of the cyclonic vortex.

K. Hinkelmann (*Germany*): *Some Experiments in Forecasting Actual Weather Development by Use of the Primitive Equations.*

In order to study the efficiency of the primitive equations as predictive tools, nonfiltered forecasting models in finite difference form have been set up, programmed, and applied to actual weather data to forecast weather developments on a nearly hemispheric area.

Two different models have been studied. The first (barotropic) considers a homogeneous imcompressible medium; it includes, therefore, external gravitational waves, and interprets the height of the model medium as a linear function of the height of the 500 mb surface. The second (baroclinic) predicts the meteorological variables within five different levels of constant pressure. By assuming hydrostatic equilibrium, sound waves are eliminated. It

was, desirable, however, to include external gravitational waves. For this purpose a special coordinate system, proposed by N. Phillips, was used internally, in which the ground level coincides with a surface of constant vertical coordinate. Only insentropic changes are considered and, where friction is included, crude assumptions are made.

In order to keep noise effects under control and their amplitudes relatively small, special but not throughout optimal adjustment operations have been applied to the initial data of wind and height fields.

Forty 72-hour forecasts with the barotropic model, and two 48-hour forecasts with the baroclinic model, have been run on a IBM-704-computer.

The results show: (1) the forecasts obtained with the barotropic, unfiltered, model have the same level of accuracy as the forecasts resulting from the filtered model, now in operational use at the JNWP-Unit in Washington. The inclusion of noise effects does not affect noticeably the large scale processes, and the obtained charts show that the superimposed noise phenomena are not obscuring the phenomena of synoptic interest. (2) Also in the baroclinic forecasts the noise components are in no way predominant, and their demonstration requests a detailed analysis. However, after a forecast period of about 48 hours, a special type of numerical instability is observed, which probably results from an inadequate description of short wave and short period oscillations by the finite difference scheme.

The large scale, synoptically interesting, processes are predicted satisfactorily, also, in the 1000 mb level, and to such an extent that the model can be considered as a basic model for further improvements. However, developments from initially small scale disturbances to large vortices are predicted very poorly by the baroclinic model. The main reason for this deficiency is supposed to be the inadequacy of the lattice with horizontal mesh width of 381 km, which does not satisfy the requirement of baroclinic models that the dimensions of the grid should approximate the discussions of shortest baroclinically unstable waves.

Discussion:

G. P. Cressman (*USA*): Our group prepared a 500 mb, 24 hour forecast chart by interpolation from Dr. Hinklemann's 400 and 600 mb forecasts. The error of Dr. Hinklemann's 500 mb forecast over North America was substantially smaller than the error of the barotropic 24 hour forecast for the same time. Also, the errors of Dr. Hinklemann's forecast were not correlated with those of the barotropic forecast.

J. Smagorinsky (*USA*): I have several questions on technique used in the 5-level forecast: (1) Were the tangential velocities at the boundary set to zero only initially, or were they held at zero during the forecast? (2) Was any horizontal smoothing done during the course of the forecast? (3) In the forecast, which could not be run past 50 hours, was skin friction included? (4) What did you do about conditional instability?

Dr. Hinkelmann (*Germany*): (1) The tangential velocities at the boundary were held at zero during the entire forecast. (2) Horizontal smoothing was done at intervals. (3) Skin friction was not included in that forecast. (4) If an upward decrease in potential temperature appeared, the potential temperatures were adjusted to eliminate this condition.

S. V. Nemtchinov (*USSR*): *Solution of an Equation to Predict the Atmospheric Pressure Field.*

This paper is concerned with the approximate solution of the equations for a quasi-geostrophic baroclinic flow. With linearized coefficients, this system of equations can be reduced to a single linear equation, in which the pressure (or isobaric height) tendency is the dependent variable. The author then approximates vertical derivatives by the method of finite differences, but retains continuous variations with respect to the horizontal coordinates. He thus generates a simultaneous system of partial differential equations in which the independent variables are the horizontal coordinates, and in which the dependent variables are the pressure changes in several discrete surfaces. It is to be noted that the coefficients of the differential operators in the latter system are constant.

The author then inverts this system of equations and shows that the system can be put into canonical form. By applying Green's method, the pressure change at *each* discrete surface can be expressed as a sum of integrals taken over *all* the discrete surfaces. The integrands of these integrals are products, one factor of which is a nonlinear function of the current

distribution, and the other is an analytic function that can be tabulated once and for all.

M. A. Iudin (USSR): Some Schemes of Numerical Analysis and Prediction in Low Levels.

A discussion is presented of several variants of a forecasting model previously proposed (1957) by the author. This model was essentially a 2-layer quasi-geostrophic model containing the effect of terrain and viscosity. Improvements in the model have been obtained by a more satisfactory representation of viscosity, and by re-programming the horizontal finite difference scheme for a tringular grid. The improvements were determined by calculations on a number of atmospheric situations using the machine 'Strela.'

A change in the model in which the ageostrophic components of the wind are used in horizontal advections is being prepared, and is expected to result in further improvements.

Sverre Petterssen (USA): Non-Adiabatic Influences on Cyclone Development.

It is now generally accepted that the bulk of the kinetic energy of the extratropical cyclones derives from conversion of available potential energy, more or less along the lines first suggested by Margules (1903). There is also much synoptic and statistical evidence (e.g., Petterssen, 1950) to show that the development of cyclones is noticeably influenced by heat sources and by sinks that are associated with the varying composition and topography of the surface of the Earth. The purpose of the present investigation has been to try to throw some light on the manner in which such heat sources and sinks affect cyclone disturbances.

A case of stationary cyclogenesis within relatively uniform cold air over the Great Lakes in winter has been investigated in some detail A method was developed with the aid of which the circulatory motion around the stationary heat source could be isolated. Though the heat source associated with the Lakes was of considerable intensity, the circulatory motion turned out to be moderate.

A large number of mobile cyclone developments on the North Atlantic have been investigated, and their life histories have been compared with the eddy fluxes of sensible heat (H_s) and latent heat (H_L), with the radiative flux (H_R), and with the rate of dissipation of kinetic energy (D) at the ocean surface. In general it is found that the H_s and H_L are about equal (with typical values of about 0 to 5 to 1 to 0 cal cm^{-2} min^{-1}), whereas H_R is about one order of magnitude and D about two orders of magnitude smaller. During typical winter situations over the North Atlantic H_s and H_L are positive and large in the cold air masses, and approximately zero in the warm air. It can be concluded, therefore, that except near coasts, the effect on cyclone developments is partly negative, in the sense that the sources of sensible heat tend to reduce the amount of available potential energy.

By superimposition of the cases examined, graphical models (representing mean states) of the various stages of cyclone development have been provided. These include the nascent cyclone, wave, the warm sector cyclone, the partly occluded cyclone, the full occlusion, the cold symmetrical cyclone, and the polar outbreak. Further work will aim at using the data contained in the graphical models to design numerical experiments that will clarify the role played by sources and sinks of heat.

Julian Adem (Mexico): A Theoretical Study on the General Circulation of the Atmosphere.

A model of the atmosphere designed for theoretical studies of the general circulation is presented. The model contains a simplified mechanism by which the energy supply of the atmosphere is fed.

To describe the behavior of the atmosphere a fluid dynamics problem in a complete form is considered. The equations for conservation of momentum, mass, and energy, and the equation of state are formulated.

Applying the conservation of energy principle to the incoming solar radiation and to the long-wave radiation, the heating mechanism is introduced. A simplified emission spectrum of the atmosphere with one transparent region is used. The surface of the Earth and a cloud layer are considered as black bodies. The Milankovitch incoming solar radiation function is used. Cloudiness is taken into account as a parameter that can easily be varied in the solution.

A numerical computation for the case of a two-dimensional atmosphere in radiative and

geostrophic equilibrium is carried out. It is shown that for such a case (in which the meridional component of the wind is zero) during spring and summer westerly winds exist in middle latitudes and easterly winds in higher and lower latitudes. However, during winter and autumn the zonal wind is westerly everywhere, except in the night region of the higher latitudes where it is zero. The winter-autumn westerly winds increase toward the lower latitudes. The solution fails as we approach the equator because we are using a geostrophic wind. The solution does not show a jet. This suggests the necessity of meridional transport of energy or momentum (or both) to account for its existence. Although the numerical computation carried out in this paper was for the very simplified case of an atmosphere in radiative and geostrophic equilibrium, it is clear that the equations can be integrated for more realistic situations. Besides, other parameters can be incorporated in the model in order to determine their role in the general circulation.

Discussion:

Fjortoft: The value you derived for the equator-to-pole temperature-difference agrees with calculations we have made, and is, in the absence of meridional flow, about twice the value observed, showing the importance of meridional transport of heat in determining the actual temperature difference.

Paul Quencey (France): *Mechanism of Maintenance of the General Circulation in the Troposphere.*

The general circulation being defined by means over at least ten days combined with zonal means, we have first studied the meridional distribution (in the troposphere) of the zonal Reynolds force F applied to a unit mass of air, and which is, by and large, opposite to the geostrophic force of the meridional wind.

One can write, in the geographical coordinate system λ (longitude), φ (latitude), z (altitude),

$$F = F_1 + F_2\,; \qquad F_1 = \frac{1}{\rho}\frac{\partial}{\partial z}\tau_{\lambda z}\,;$$

$$F_2 = \frac{1}{\rho r\cos^2\varphi}\frac{\partial}{\partial\varphi}(\tau_{\lambda\varphi}\cos^2\varphi);$$

$$\tau_{\lambda z} = \overline{(\rho u' w')}; \qquad \tau_{\lambda\varphi} = \overline{(\rho u' v')}.$$

where ρ is density, r is radial distance, and u', v', and w' are the components of the wind perturbation. F_2 is the 'Rossby force' or the contribution of the net meridional exchange of momentum, F_1 is the force of friction or the contribution of the net vertical exchange of momentum, and $\tau_{\lambda z}$ and $\tau_{\lambda\varphi}$ are the corresponding components of the Reynolds tensor. We have also studied the meridional distribution of F_2, and have concluded that the subtropical perturbations of the upper troposphere (through their mean dynamical effect) account for the essential properties of the general troposphere circulation.

Finally, we have proposed and discussed the formula for a generalization of the law of molecular viscosity

$$\tau_{\lambda\varphi} = k_2\frac{\partial}{\partial\varphi}(\rho\omega\cos^2\varphi)$$

n which ω = absolute angular velocity. We have studied also the meridional distribution of the exchange coefficient k_2, which is a maximum at about 30° latitude in the upper troposphere.

H. H. Lettau (USA): *A Unified Model of Boundary Layer Structure for Atmospheric Flow and Turbulent Duct Flow.*

A new solution for the frictional wind profile in the thermally neutral planetary boundary layer is based on an integration of the equation of motion. Three external parameters are considered, namely, the horizontal pressure gradient (or, the geostrophic speed), the Coriolis parameter, and the roughness length of the surface. These three external parameters determine the surface Rossby Number ($V_g/z_0 f$), which is the significant scale factor of the solution. No empirical coefficients other than the Karman constant are used. The essential feature of the approach is a generalized expression for the characteristic scale of eddies responsible for momentum diffusion, as a non-monotonic function of the distance from the lower boundary. The generalized expression applies also to flow of incompressible fluids in a rough pipe at high Reynolds numbers. The unified theory permits us to predict, for a given surface Rossby Number, the dynamically most important parameters of planetary boundary layer structure. Examples are the thickness of the surface

layer (i.e., the stratum where the wind profile is closely approximated by the logarithmic law), the intensity and direction of the surface stress, the vertical profile of shearing stresses, the height of the 'geostrophic wind level', the total dissipation of mechanical energy, eddy diffusivities as a function of height, and other turbulence quantities. The effects of thermal stratification (Richardson number), and baroclinity (thermal wind, or geostrophic shear) are also discussed.

From detailed topographical measurements in Wisconsin, characteristic roughness lengths are determined, with verification being obtained by observation of the actual low-level wind flow. Calculations of roughness lengths characteristic of vegetation are also presented. It is concluded that vegetation is more important than variable terrain in producing surface stress and energy dissipation.

Discussion:

A. M. Oboukhov (*USSR*): It is known that the value of the drag coefficient depends on the static stability, but I do not believe that you have indicated this effect in your discussion of numerical values.

H. H. Lettau (*USA*): The drag coefficients I presented are characteristic of average conditions of static stability.

D. R. Davies and M. B. Oakes (*England*): *Formulation and Integration of the Equations of the General Atmospheric Circulation.*

(1) Equations describing the mean flow of a spherical shell of turbulent air surrounding a rotating spherical Earth are formulated by employing the Reynolds method of averaging, over a period of a year, the hydrodynamic equations expressed in spherical polar coordinates. The viscosity terms and those Reynolds stress terms involving the reciprocal of the radius of the Earth are neglected, leaving shearing eddy stress components in the meridional and zonal directions. The complete problem of solving the thermodynamic and dynamic equations in spherical coordinates simultaneously has not yet been attempted, and empirical formulae are used to describe the averages of temperature and density distributions. These are taken to have been averaged over zonal circles and to be symmetrical about the equator, and the problem then consists of integrating the ensuing dynamical equations.

(2) An approximate solution is obtained first. This is based on (i) a linearisation of the inertia terms, and of terms involving the deviation of density from a convenient constant value, (ii) the assumption that the Reynolds shearing stresses are linearly dependent on mean velocity gradients, the proportionality coefficient (or eddy viscosity) K being taken to be both a constant and a function of latitude, and (iii) the retention of only the dominant Coriolis force and turbulence stress terms. The mean flow equations then represent a balance between pressure gradient and Coriolis, turbulence, centrifugal and gravity forces; the last two depend on density, and hence on latitude and height above surface. A solution is constructed by a method similar to that used by M. H. Rogers (1954) in an analysis of the viscous flow equations; this was based on a density distribution which was effectively independent of height, and the centrifugal term was neglected. The formulae obtained for meridional and zonal velocities are computed, using firstly constant K values, and secondly K depending on latitude. The value 5×10^{10} cm^2 sec^{-1} has been suggested by Durst (1959) from large scale particle diffusion, but 1×10^9 cm^2 sec^{-1} has been used successfully for momentum transfer by Phillips (1956), and a possible dependence of K on latitude can be deduced from Lettau's (1936) values for large scale meridional heat transfer. Alternative forms of surface and tropopause boundary conditions are also considered.

By using an expansion method similar to that developed in 1954 by Rogers an approach can be made to the problem of evaluating the influence of the non-linear inertia terms. The analysis is, however, difficult to develop numerically, and numerical evaluation is being carried out first in the limiting case of very large angular velocity.

(3) The meridional velocity distribution has been calculated from the linearized model for K (cm^2 sec^{-1}) $= 5 \times 10^{10}$ and for $K = 10^9$. At the larger K values the calculated meridional velocities in the lower troposphere are considerably larger than observed values given by G. B. Tucker (1959), but the calculated and observed changes in northerly or southerly directions of mean flow take place at approximately the same latitudes. As expected, the smaller value of K leads to smaller calculated

velocities, of magnitudes similar to observed values. Zonal and vertical velocities, meridional transports of angular momentum, and the effect of taking K to depend on latitude are also being evaluated numerically.

Arnt Eliassen (Norway): Vertical Circulations Connected with Fronts.

The important of vertical circulations for the dynamics of fronts has been stressed by several writers. Thus, for instance, J. Bjerknes (1) has related the upgliding motion to the acceleration along the front, and Newton (2) has shown how the vertical circulations can be determined from a diagnostic use of the dynamic equations, when the time changes are known from successive synoptic charts.

The present study is an attempt to apply quasi-balanced dynamic theory to determine the general types of vertical circulations that will be set up in frontal zones, and the factors that are responsible for their existence. A similar investigation has been made by Sawyer (3), and the present work may be considered as an extention of Sawyer's paper. Reference is also made to a paper by the author (4), in which the vertical circulations caused by surface friction and heat of condensation in frontal clouds and their effects upon the development of the front are studied, and to a paper by the author presented at the Fortieth Anniversary meeting of the A.M.S., January 1960, in which most of the results of the present paper were given.

It is a characteristic property of a frontal zone that the gradients of wind and temperature along the zone are small compared with the gradients across it. This circumstance may be used to simplify the equations, in much the same way as this is done in boundary layer theory. When this simplification is made in the balance equation, the non-linear terms drop out. As a result, one arrives at the conclusion—when the variation of the Coriolis parameter is ignored—that the geostrophic wind carries all of the vorticity and none of the divergence. Moreover, it follows that the ageostrophic motion is directed across the front (approximately); together with the vertical motion, it forms a vertical circulation along closed streamlines in transverse vertical planes. A non-homogeneous, elliptic differential equation for the stream function defining the vertical circulation is derived from the equations of motion and the thermo-dynamic energy equation. The form of this thermo-dynamic equation shows that the ascending and descending branches of the vertical circulation cells tend to be parallel with the absolute vorticity vector, which is directed upwards roughly along the frontal slope. From a study of the forcing terms appearing on the right-hand side of the equation, the following conclusions can be drawn. (a) A horizontal deformation field resulting in a stretching of the frontal zone will cause a direct circulation, i.e. ascent on the warm air side and descent on the cold air side of the frontal zone. This is the effect dealt with by Sawyer. Qualitatively, this result can be obtained by simple reasoning (Namias and Clapp (5); Eliassen (4)). (b) A thermal wind component across the front towards the warm air gives likewise a direct circulation. (c) Increase and decrease of the frontal shear along the front in the direction of the thermal wind causes descent and ascent, respectively, in the frontal zone, and ascent and descent, respectively, in the air masses on both sides. (d) Surface friction causes ascending motion in the frontal zone; the corresponding descending branches may be far away from the front. (e) Release of latent heat and precipitation will cause a strengthening of the vertical circulations, and a concentration of the ascending branches.

The changes in frontal structure produced by the vertical circulations are discussed.

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4. Eliassen, A., *On the formation of fronts in the atmosphere. The Rossby memorial volume*, Rockefeller Inst. Press and Oxford University Press, New York, p. 277, 1959.
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Discussion:

Dr. Fjortoft asked how the slope of a front (normal to the front) could remain unchanged if

there were a component of the geostrophic wind *shear* normal to the front, i.e., if the isotherms intersect the front. Professor Eliassen replied that, if there did exist a component of the geostrophic wind shear normal to a front, there would also be an induced shear of the *non*-geostrophic wind, such that the latter almost exactly cancels the former. In short, owing to the dynamical properties of fronts, the *total* wind shear normal to a front is small, and the slope of the front remains more or less unchanged.

V. I. Gubin (USSR): Calculation of the Measure of Frontogenesis at Average Level.

(1) An absolute derivative of the modulus of the logarithmic temperature gradient is adopted as a measure of frontogenesis. The distribution character of the measure at this or that isobaric surface and at the average level as well (500 mb) makes it possible to judge the deformation direction of the frontal zone.

(2) The scheme of calculation of the measure of frontogenesis at the 500 mb level is given. It is applied for use on the electronic machine. The calculation scheme is based on a two-level model of atmosphere.

(3) The calculation was made on the electronic computer 'Strela'. The mesh consisted of 391 units (23 × 17) with an interval of 250 km.

(4) Examples of frontogenetic conditions are given for some acrual situations, with analyses of the results.

Frank B. Lipps (USA): The Stability of the Jet Stream.

This paper considers the stability of a jet stream. The motion is assumed to be horizontal, non-divergent, and barotropic. The jet is assumed to be of the form $U(y) - A(\operatorname{sech} b\,y)^x + B$. The perturbations are required to approach zero as $y \to \pm\infty$. After non-dimensionalization we introduce the non-dimensional wave number l and a parameter, χ, which is a measure of the rotation effect. χ is inversely proportional to β, the Rossby parameter.

There are only two kinds of perturbations: symmetric disturbances (those with maximum amplitude at $y = 0$), and asymmetric disturbances (those with zero amplitude at $y = 0$). We find the neutral curve in the χ, l^2 plane for both types of disturbances. The rates of amplification in the immediate vicinity of the neutral curve are also found for both types of perturbations. For the symmetrical disturbances we find a band of unstable wavelengths when $\chi > \frac{1}{2}$; for large χ the curve of maximum instability is asymptotic to the lower branch of the neutral curve. The asymmetric disturbances are more stable than the symmetric disturbances; this may explain partly why such waves are not observed in the atmosphere.

Atmospheric data show that the mean hemispheric winter jet (1949) is stable as a whole, but has regions of instability associated with regions of cyclogenesis. To compare atmospheric data with the above theory, we consider a neutrally stable jet ($\chi = \frac{1}{2}$) and find $n = 7.2$ for the wave number of the neutral wave. This compares well with the maximum at $n = 6$ in observed perturbation spectra. In a region of maximum cyclogenesis (80°W) we find that perturbations with wave numbers 6, 7, and 8 are unstable. The maximum rate of amplifications is 8.7 days for wave number 7.

Discussion:

Some question arose as to the interpretation and application of Dr. Lipps' results. In particular, the nondimensional wave length is defined relative to the effective width of a jet-like average velocity profile whose shape is arbitrarily specified. Accordingly, because real average wind profiles do not always have the assumed shape, it may be difficult or impossible to compare the predicted behavior of Dr. Lipps' model with that of the atmosphere.

A. S. Dubov (USSR): The Influence of Mountains on the Motions of Cyclones.

Synoptical experience shows that mountains essentially affect the motion of pressure-patterns, but the theory has not yet been studied in full. In the present paper an attempt is made to develop a theory on the influence of orography on the motion of pressure centres.

The theory is based on the formula for the velocity of motion of cyclones, where the velocity is shown to depend on the value of ageostrophic wind, which may be computed using a special method devised by Yudin. Formulae were developed to compute the ageostrophic wind components due to surface friction and the relief of the Earth's surface. Using this theory, a method of forecasting the motion of cyclones in mountain regions has been worked out and tested.

It is demonstrated that the influence of surface friction on a plane surface is practically insignificant when the motion of pressure centres is being determined.

Simple formulae have been developed for the correction to the velocity vector of the pressure centre due to the influence of mountains. The formulae show that this correction is related to the relief in the same manner that the geostrophic wind is related to the relief field of the isobaric surface. In particular, the influence of an isolated peak on the motion of a pressure centre reduces to the rule that the centre seeks to pass round the peak in the anticyclonic direction.

The method of forecasting the motion of cyclones in a mountain region is a combination of the method of spatially-smoothed flow, which has been suggested by Ludin to forecast cyclone motion over a plane surface, and the methods of computing the corrections caused by the relief effect. All the corrections are calculated using smoothed relief maps and are included when constructing the cyclone trajectory step by step with two-hour intervals.

The presented method has been tested on the data for cyclones crossing the Urals and the Scandinavian mountains. Tests of the method have proved that taking account of the influence of mountains permits an essential improvement in the accuracy of forecasting cyclone motion.

Sverre Pettersen (USA): Comments on Symposium on Dynamical Processes in the Atmosphere.

According to the program it is my assignment to summarize and comment on this symposium which has occupied our thoughts for two full days.

The first thought that naturally comes to the minds of all of us is one of gratitude to Dr. Thompson who has organized this very stimulating conference. The second thought that came to my mind can best be indicated by paraphrasing Paul Winterton, who said that "there are no real experts on Russia—only varying degrees of ignorance". Now, after having heard the 19 papers presented at this symposium, I am beginning to believe that we really have experts—as well as varying degrees of ignorance.

Although our level of knowledge may not be too impressive, I believe we have good reason to be proud of the rate of progress. I don't think I am very wrong when I say that the bulk of our knowledge of the dynamics of the atmosphere has come to us during the last ten or fifteen years, and we may well ask ourselves why this is so. Obviously, one reason is better observations, particularly from the upper atmosphere. But observations do not really solve problems—there must be more to it than just an increase of data. More important, I think, is the general progress in science and technology. For example, there was an almost discontinuous development in meteorology after the invention of telegraphy, and similar development occurred after radio came into general use. At the present time, I am inclined to place emphasis on the electronic computer. I am mentioning this not only as a servant but also as a master. I am sure that the psychological effect of its presence has caused us to be far more daring; we have formulated problems on a level far beyond our imagination in earlier years.

Another important source of stimulation has been created in our hydrodynamical laboratories. I am referring to experiments with rotating fluids with sources and sinks of heat. Such physical experiments and simulations of the dynamical processes of the atmosphere have opened up fascinating fields in recent years. Thus, the numerical experiment on the electronic computer and the physical experiment in the so-called dishpan have unravelled some of the secrets of the atmosphere—at least in broad outline. And we are still moving forward at good speed.

But it is possible to identify a third and very appealing trend. The Laplacian dictum of complete predictability has been shaken, notably by Sutcliffe, and the works of Wold, Kolmogorov, Wiener and others have been translated into statistical models which will make the atmosphere yield up some of its secrets. Here, we find predictability with a margin—not complete determination.

There is of course the old-fashioned method of analysing plain meteorological observations, and we must not ignore it. In fact, in this symposium, yesterday and today, we have had contributions from all four fields: physical hydrodynamics, disphan experiments, statistical simulations, and data analysis. It is this combination of approaches, rather than any particular

contribution, that has set a standard at this symposium.

At our first session we heard four important papers on the general circulation. In three of these we became acquainted with important extensions of the theory of the circular vortex, which used to be highly symmetrical. Conventional meteorologists will be pleased to see that the circulation is treated now not as a steady state, resembling the observed mean, but rather, it is allowed to select certain unstable modes, to vacillate between certain extremes, and to shuffle energy back and forth between the modes and the mean current. This, indeed, is progress.

Some of the conventional meteorologists will see here a resemblance to the so-called index cycle, and the dishpan experimenter sees the same result in his rotoscope. This is all very encouraging. But many meteorologists will say that the atmosphere does not often reproduce the index cycle, and that when it does so, it produces a rather complex affair, without much global symmetry. It seems to me that both theory and experiment have become slightly partial to the index cyclists. Whatever the case may be, the practical meteorologist has to cope with the atmosphere as it actually is, and he is rather impressed by the bold approaches of Smagorinsky, Mashkowich, and Faller, who allow asymmetries and try to account for the influences of oceans and continents. This, certainly has a strong appeal to the weather forecasters, and they will wait for further enlightenment. They could, of course, produce some enlightenment themselves.

In the past, we have been apt to take the vertical structure of the atmosphere for granted, and we have tended to be so hydrostatic and geostrophic that we have paid little attention to the energy propagations. I was greatly impressed with the beauty of Charney's paper. We learn from it that the structure of the general circulation is such that the energy of the planetary waves cannot escape to great heights. However, there remains to explain the general circulation itself.

All weather forecasters, I am sure, got much enjoyment out of the papers presented at the second session. Here we find an almost ideal merging of physical, statistical and synoptic models. What could be more pleasing.

It is not too easy to summarize the discussion at the third session except to say that the contributions were important. They ranged over all scales from turbulence to cyclones and global circulations. Here again, we are reminded that turbulence is fundamental to the understanding of the dynamical processes on all scales.

The discussion of this last session is so fresh in our minds that no summary seems necessary. Though all papers were fascinating I was particularly pleased to see that the problem of frontogenesis has begun to yield to dynamical, rather than kinematical, treatment. Also, as a forecaster, I was pleased to see such an inspiring discussion of orographic influences on cyclones. We have done some work on related problems in Chicago, and I am sure there is here a fruitful field for further research.

So much for the papers themselves. Now, if we ask ourselves what we have achieved at this symposium, I think the answer must be that we have brought theory closer to observation, and that we have done so faster and in greater volume than in the past. At this symposium, we have heard nothing about the two-dimensional incompressible fluid. Instead, we have discussed the dynamics of thermally active substances. To some extent we have appealed to heat sources and frictional controls, and we have clarified many aspects of the instabilities that control the motion and weather systems.

Next, if we ask ourselves where we are going from here, I can contribute only by referring to a prediction I made in 1956, namely, that statistical techniques will find increased applications and that we may hope for a merging of hydrodynamics and statistics, particularly in problems where prediction is involved. The discussions of this symposium have, I believe, shown that we are heading in that direction.

Symposium: Tsunamis and Storm Surges

Reported under Physical Oceanography.

Symposium: Atmospheric Chemistry and Radioactivity

This constructive symposium was held as part of the International Union of Geodesy and Geophysics, XIIth General Assembly, Helsinki, Finland, on August 2nd and 3rd, 1960 by the International Association of Meteorology and Atmospheric Physics. *W. Bleeker*,

(*The Netherlands*), the Chairman of the opening session and President of the Commission on Atmospheric Chemistry and Radioactivity, announced that the purpose of the symposium was, to demonstrate the usefulness of stable and radioactive substances in the atmosphere for the benefit of meteorology. Accordingly, the major papers, by invitation, surveyed limited areas. This did not restrict the meeting to old information, for many speakers reported on data and interpretations not published previously.

The sessions started with a discussion of stratospheric tracers. *K. R. Ramanathan* (*India*) and *H. Paetzold* (*Germany*) reviewed the newly emerging ozone pattern, showing a shortage of ozone to about seven Km above the equatorial tropopause, and the excess ozone in the polar winter relative to equilibrium conditions. Both found support for a meridional circulation, although the details differed. *E. A. Martell* (*USA*) showed how Rh-102, a radioactive tracer, added at an altitude of over 100 Km in August 1958 (at 17°N) appeared after the summer of 1959, with higher stratospheric concentrations nearer the pole than the equator. Very recent observations by Martell disclosed the Rh-102 to be in the stratosphere of both hemispheres. Martell also discussed W-185, added in the summer of 1958, but at 11°N in only the lowest part of the stratosphere. The Bedford, Massachusetts rains showed a seasonal peak in the spring of 1959 which, when converted to Sr-90 was much less marked than the Sr-90 peak attributed to the USSR Arctic nuclear tests of October 1958. *L. Machta* (*USA*) showed a series of stratospheric patterns produced by the U. S. Department of Defense (Defense Atomic Support Agency) high altitude sampling program (HASP), which indicated that the peak W-185 remained at the approximate latitude of injection for at least 18 months after the input.

It was apparent that a sharp division exists between two groups of meteorologists on the need for a meridional circulation in the stratosphere. On the one hand, many, if not most, meteorologists cannot accept such a circulation on hydrodynamic and possibly thermodynamic grounds. On the other hand, the interpretation of many tracer studies is greatly simplified by a Brewer-type model. Considerable interest was exhibited, therefore, in the stratospheric W-185 measurements which, at face value, do not require any such circulation.

The transport of fission product radioactivity into the troposphere, and its washout were discussed by *Stewart and Pierson* of the United Kingdom. The British data show a clear seasonal trend in long-lived fission products, coming from the stratosphere with a spring maximum and an autumn minimum. Both *D. H. Pierson* (*Gr. Britain*) and *N. G. Stewart* (*Gr. Britain*) attributed deposition of Sr-90 and Cs-137 primarily in the United Kingdom to rain removal and related air content and rainfall rates to the total deposition. Pierson noted that the lower stratosphere had a diffuse peak, usually in mid-winter, suggesting a possible quarter of a year lag for the maximum to reach the ground. He also pointed out that the tropospheric contained fission products that had a different composition than the stratosphere directly above the United Kingdom, so that the temperate zone troposphere was being fed by U.S.S.R. Sr-90 through the polar tropopause (the mechanism or exact location being unknown at this time) rather than by southward mixing of the U.S.S.R. Sr-90 through the stratosphere to United Kingdom latitudes, and thence into the troposphere. Stewart increased his earlier estimates of mean tropospheric storage time from 30 to 35 days, to over 40 days. However, the decrease of Sr-90 or Cs137 in the troposphere during the summer of 1959 would place a maximum value of about 30 days on this time. *Tavaersky* showed detailed pictures of the air content and fallout in various parts of France; the results were typical of those in Western Europe.

A major emphasis was placed on natural radioactivity. Two fine survey papers by non-meteorologists, *B. Peters* (*Denmark*) on cosmic ray radionuclides, and *W. Jacobi* (*Germany*), on Berlin ground source radioactivity brought the status of knowledge up to date. *G. Schumann* (*Germany*) showed why it was likely that the very short residence time derived from the radon Ra-D measurements were underestimates. *L. Machta* (*USA*) produced a model of tropospheric diffusion and particulate removal based on United Kingdom measurements, and new upper air Ra-D measurements from the United States, and only partly verified by new United States upper air Be-7 measurements. The same Be-7

and some new HASP world-wide Be-7 measurements were used to demonstrate a lack of equilibrium of Be-7 stratospheric concentrations as suggested by Peters. There was a feeling that a bright future exists for natural radioactivity in meteorology.

F. Begemann (*Germany*) and *E. W. Barrett* (*USA*) showed some applications of Tritium (both gaseous, and in water vapor) to meteorology. Much work is yet to be done in this field. Barrett's estimate of a very short stratospheric storage time, 0.29 years, based on the 1959 decrease in HTO at Chicago was criticized. The existence of three sources—cosmic rays, nuclear tests, tritium production plants—requires especially careful evaluation of present day measurements of tritium.

On the other hand, both *E. S. Epstein* (*USA*) and *Dansgaard* presented convincing evidence for their interpretation of processes that control the changes in the O^{18}/O^{16} and D/H ratios in precipitation, that is, analogous to multiple stage distillation. The positive correlation between lightness of rain water and decreasing condensation temperature was illustrated almost literally from pole to pole. Dating of ice cores from summer-winter changes in the O^{18}/O^{16} was shown by Epstein; for large gross samples, Dansgaard was able to date icebergs from the same ratios.

An important contribution to knowledge of stratospheric dust was given by *C. E. Junge* (*USA*) in an updating of his Boston AMS presentation. Results of aircraft and balloon measurements suggests an unexpected vertical distribution of particles greater than about 0.1 microns, increasing in concentration to about 70,000 feet, and being composed of a large fraction of sulfur. Junge's suggested explanation brings the sulfur aloft as H_2S or SO_2 and by the action of sunlight converts it to compounds that can be filtered from the air.

R. M. Goody (*USA*) reviewed and analyzed the information derivable from optical measurements of the upper atmosphere. With the exception of some deductions made from observations of noctilucent clouds, the methods of analysis are extremely laborious and uncertain because of the attenuation coefficients and scattering parameters in the lower intervening atmosphere.

Witt (*Sweden*) presented some remarkable moving pictures of noctilucent clouds. Photometric observations, of promise a few years back, were shown not to be of great utility in the solution of the problem of obtaining vertical dust distribution. The measurement of the absolute intensity of twilight phenomena by means of precision photometers capable of discrimination in a narrow spectral range was thought to be capable of distinguishing mesospheric aerosols, but, again, this was complicated, and the whole atmosphere must be taken into account to allow for the effects of attenuation of light rays at various altitudes.

E. Eriksson (*Sweden*) and *H. Geogii* (*Germany*) reviewed the field of the chemistry of rain water and atmospheric trace gases respectively. Eriksson showed evidence that the higher chloride content of rains near the coast are derived from the oceans. He also argued that the sulphur is mainly from industrial origin, but that the interpretation of nitrogen compounds was more difficult. Eriksson showed maps of precipitation chemistry measurements over many parts of the globe, and pleaded for improved networks.

E. S. Selezneva (*USSR*) showed that the U.S.S.R. had a network of 12 stations, which she said would be expanded in the future. *R. A. McCormick* (*USA*) indicated that the U. S. Public Health Service and Weather Bureau now operate 30 collection stations, primarily a reactivation of the network initiated by Junge several years ago. Geogii reviewed the difficult field of atmospheric trace gas chemistry. He emphasized the need to separate the trace gases from the aerosols before analysis.

This conference did not result in either a comprehensive exchange of information or an adequate evaluation of what was presented; nor was it intended to achieve these ends. There was inadequate time for discussion, despite the fact that almost all sessions extended well beyond scheduled periods. The excellent contributions of the non-meteorologists suffered occasionally from naive or incomplete meteorological interpretation. These and other shortcomings, it is hoped, will be remedied in a symposium on the same subject to be held in 1962, on the advice of the IUGG Commission on Atmospheric Chemistry and Radioactivity.

Symposium: Circulation of CO_2 in the Atmosphere and the Ocean

Reported under Physical Oceanography.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

GEOMAGNETISM AND AERONOMY

General Report

The International Association of Geomagnetism and Aeronomy held meetings throughout the period of the IUGG General Assembly.

All eleven of the regular Committees held meetings at which technical papers were presented; because of closely related interests, several of the Committees held combined sessions.

As in the past, the Association suffered by not having a detailed schedule of papers available at the beginning of the assembly. Nevertheless, very profitable technical sessions were held. The technical papers were organized into committee sessions that closely paralleled the 11 permanent committees, and into four symposia.

Because of the great number of participants (329 registered) and of scientific communications submitted for presentation (about 200) it was necessary to arrange the time-table in such a way that meetings of different groups were held at the same time but so as not to interfere with plenary sessions of the Association. In this respect, as in all others, it must be said that, the arrangements made by the Finnish Committee proved highly satisfactory and efficient.

The Executive Committee of IAGA held three formal meetings (25th July, 4th and 5th of August). The following nominations of IAGA representatives made during the interval between the Toronto and Helsinki meetings were ratified: V. Laursen as reporter for Geomagnetism in CIG, M. Nicolet for the Inter-Union Committee on the Ionosphere, J. Veldkamp as representative of Center C in CIG, and J. Bartels and M. Nicolet for the Mixed Commission on Solar Terrestrial Relationship. Also appointed were: *Nominating Committee*: Bartels (Chairman), Benkova, Bouska, Coulomb, Elvey and Romana; *Resolutions Committee*: Ianovsky, Jacobs, and Selzer; *Finance Committee*: Thellier (Chairman), Nagata, and Nicolet.

Some time was devoted to the problem of *publications*: After a long discussion it was decided not to propose to the General Assembly a change in the Statutes of the Association in order to include the Editor in the Executive Committee.

It was the general feeling that the IAGA publications appear too late. Remedies were sought, and it was decided (1) to draw a dead line for the submission of manuscripts (which for documents to be printed in the Helsinki Transactions was fixed on the 31st December 1960); (2) that in the future National Reports should be brief (not more than 10 pages) and in a standard form to be prepared. Later, following an IUGG recommendation, it was decided not to include the National Reports in the Transactions. It seems desirable that the reports prepared by the chairman of the IAGA Committees should be, in general, more comprehensive, and to include a bibliography, if possible.

The free distribution of the Transactions will be followed in future, but for Symposia the free distribution should be restricted to not more than one or two copies per National Committee.

It was resolved that in the next period IAGA would arrange three symposia: in 1961 'Earth Storms' at Kyoto; in 1962 'Paleomagnetism and Paleoclimates' in Paris, and a third in 1963, just before the General Assembly on Aeronomy in California. The conveners will be Nagata, Thellier, and Nicolet.

As for the future of the World Data Center, IAGA was in favour of the continuation of them, at least until the end of 1965 (see resolution 12).

There was also a very general agreement on the importance of conducting a world-scale study of geophysical phenomena during the period of

minimum solar activity as some sort of a reduced and voluntary IGY during the next solar minimum.

A great deal of time was devoted to the study of the *World Magnetic Survey*. Unfortunately there were too many different opinions to permit putting together at this time a very precise agreement. The IAGA Executive Committee agreed to list responsibilities for the conduction of the WMS (Resolution 5), and adopted a few resolutions that will help the implementation of the project (Resolutions 6–8), and endorsed the technical recommendations prepared by IAGA Committee no. 5 (see IUGG Chronicle no. 16 pp. 29–30, 1960). It was decided also to approach the CIG in order to obtain its agreement on the compilation of the rough and reduced data, and through an IUGG Resolution the addition of a discipline member for WMS was proposed to the CIG; if the proposal is accepted by the CIG, E. H. Vestine was nominated as discipline member.

Many other problems were discussed during the Meetings. Some of them appeared finally in the form of recommendations resolutions adopted by IAGA or by the IUGG, and others, of minor importance, were circulated to interested persons or organizations.

The Secretary of IAGA was not able to produce, before the end of the General Assembly, a budget for the next triennium, because the Finance Committee of the Union could not indicate until the last day, the yearly allowance made to the Association. The Secretary was instructed to prepare a budget on the same lines as that made at Toronto, and to circulate it to members of the new Executive Committee for comments and approval.

In the last General Meeting of the Association the following Officers of the Association, Committee Chairmen, and USA Committee members were elected:

OFFICERS

President: V. Laursen (Denmark)
Vice Presidents: M. Nicolet (Belgium)
N. Pushkov (USSR)
Secretary, and Director of the Central Bureau: J. V. Cardús (Spain)
Executive Committee: J. Bartels (Germany); J. Bouska (Czechoslovakia); J. Kaplan (USA); T. Nagata (Japan); O. Schneider (Argentina); E. Thellier (France).

Committee Chairmen, and Committee Members for USA

1. *Observatories*: G. Fanselau (Germany), Chairman; E. B. Roberts

2. *Aurora and Airglow*: C. T. Elvey (USA), Chairman; J. E. Blamont, K. C. Clark, J. W. Chamberlain, T. N. Davis, W. G. Fastie, C. W. Gartlein, N. J. Oliver, D. M. Packer, M. H. Rees, F. E. Roach, L. Wallace

3. *High Atmosphere*: M. Nicolet (Belgium), Chairman; C. A. Barth, J. E. Blamont, F. R. Boyd, L. M. Branscomb, J. W. Chamberlain, S. Chapman, T. A. Chubb, A. Delgarno, J. Dorman, H. Friedman, R. A. Helliwell, J. P. Heppner, H. E. Hinteregger, R. Horowitz, L. G. Jacchia, R. Jastrow, C. Y. Johnson, F. S. Johnson, H. Kallman-Bijl, J. Kaplan, S. A. Korff, P. Mange, H. E. Newell, A. O. C. Nier, E. C. Ray, M. H. Rees, J. C. Seddon, S. F. Singer, F. W. Siry, J. A. Simpson, C. P. Sonett, R. Tousey, J. A. Van Allen, T. Van Zandt, F. L. Whipple, C. A. Whitney

4. *Secular Variation and Paleomagnetism*: T. Nagata (Japan), Chairman; J. R. Balsley, H. H. Howe, J. H. Nelson, E. H. Vestine

5. *Magnetic Charts*: J. Keränen (Finland), Honorary Chairman; E. H. Vestine (USA), Chairman; B. C. Byrnes, A. J. Dessler, J. W. Joyce, E. Maple, J. H. Nelson

6. *Lunar Variations*: S. Chapman (USA), Honorary Chairman; O. Schneider (Argentina), Chairman; J. C. Cain, E. J. Chernosky, B. Haurwitz, H. H. Howe

7. *Magnetic Comparisons*: V. Laursen (Denmark), Chairman; E. B. Roberts

8. *Magnetic Instrumentations:* J. H. Nelson (USA), Chairman; M. E. Packard

9. *Characterization of Magnetic Activity*: J. Bartels (Germany), Chairman; E. J. Chernosky, H. H. Howe, H. F. Johnston, J. V. Lincoln

10. *Rapid Variations and Earth Currents*: F. A. Romañá (Spain), Chairman; V. P. Hessler, J. H. Nelson

11. *History of Geomagnetism and Aeronomy*: N. V. Poushkov (USSR), Chairman; E. J. Chernosky, C. W. Gartlein, N. C. Gerson, E. B. Roberts

IAGA-CIG: V. Laursen (Denmark), Chairman; C. T. Elvey, E. H. Vestine

Joint Committee on Atmospheric Electricity: H. Norinder (Sweden), Honorary Chairman; L. Koenigsfeld (Belgium), Chairman; S. C. Coroniti, H. W. Kasemir

IUGG-COSPAR (IAGA Membership): J. E. Blamont, R. Jastrow, J. A. Van Allen.

RECOMMENDATIONS

The following recommendations were voted by the Association.

I

The IAGA recommends the adoption of the following report of the sub-committee of Committee 2 and recommends that the IUGG give financial support to the project.

Report of sub-committee on Revisions of the Photographic Atlas of Auroral Forms and of the International Nomenclature or Classification of Aurora.

The subcommittee notes that the present use of auroral nomenclature is not uniform in the different countries and observing networks. It also notes that the Photographic Atlas of Auroral Forms is now out of stock. An illustrated guide on auroral morphology to secure uniformity of nomenclature on which most auroral workers can agree is considered a necessity for observational and theoretical purposes. It is the belief of the Working Group that it is the responsibility of the IAGA to provide such a standardized nomenclature.

This could best be achieved by establishing within the IAGA Committee No. 2, a Sub-Committee on Revision of Auroral Forms and Revision of Auroral Classification, which should be instructed as follows:

1. Discuss the convenience of maintaining, altering, or broadening the morphological classification given in the present Atlas, taking into account the more complete observational data and experience now available from within, under, and outside the auroral zones of both hemispheres.

2. Select a set of representative photographs suitable for printing a new atlas to illustrate the classification, taking advantage of the present Atlas, and of any additional photographic data available, including Professor Strömer's collection if available.

3. Decide upon the possibility of including color photographs, which is considered desirable, provided that a reasonable degree of color fidelity can be attained in their reproduction.

4. Give full morphological description (including time, place, color, intensity, stability) as well as photographic references for each selected picture.

5. Consider the possibility of an abridged version of the new Atlas, suitable for non-professional observers.

6. Include a section with characteristic examples of All-Sky camera pictures, classified in accordance with the nomenclature adopted.

7. Accomplish the selection of pictures, wording of definitions, and editing, not later than July 31, 1962.

8. Submit to the Executive Committee of the IAGA an estimate of extent and probable cost of publishing, not later than December 31, 1961.

The IAGA should invite the collaboration of individual scientists, institutes, and amateurs all over the World in providing auroral photographs and descriptions, as well as suggestions.

The new Atlas should be published by, or under the auspices of the IAGA, or the IUGG.

The present Sub-Committee suggests for nomination to the proposed Sub-Committee of IAGA Committee No. 2, the following: Paton (Chairman), Isaiev, Gartlein, Jacka, Schneider, and an auroral investigator from Scandinavia or New Zealand. The Sub-Committee should be free to request the collaboration of others.

The present Sub-Committee considers that it would also be advisable to attempt a better international standardization of schemes for visual observation and photographic recording, and suggests that a Sub-Committee on Methods of Observation be established.

II

The IAGA, considering that for the understanding of world-wide cosmic ray phenomena, data should be available from stations from different points all over the Earth, and, since there is no other station within many thousands of kilometres of Hermanus, Cape Province, and Union of South Africa, emphasizes the importance of having the flow of data from Hermanus continue, and hopes that the authorities will continue to support the operation of the cosmic ray observing equipment at this station.

III

The IAGA, considering the fact that the IAMAP has established a Committee on 'Meteorology of the Upper Atmosphere', and considering the need for complete information on this type of work, urges its Secretary to pass to the IAMAP Secretary all pertinent information.

IV

The IAGA recognizes the importance of the publication of the most recent data on the Earth's magnetic field, requests all magnetic observatories to send regularly and as soon as possible the annual mean values of the magnetic elements to the Chairman of the Committee on secular variations and paleomagnetism who will be responsible for the prompt compilation of the data as well as its publication in an appropriate form.

V

The IAGA, considering the CIG resolution on the meeting held in Paris (March–April 1960), recommends that the following lists of responsibilities be established for the conduct of the WMS: (a) IAGA will take the responsibility for the scientific program and consultation related to the project. If there is a need for a bureau to be established this will be the responsibility of IAGA, and IAGA must support it financially. Coordination with national IUGG committees will be secured by IAGA, through the IUGG. (b) CIG will help in coordinating the work through national CIG/IGY committees and in obtaining financial support for the project. (c) For interdisciplinary areas, CIG, COSPAR, SCAR, and other similar bodies will be approached by IAGA through the IUGG-COSPAR or other pertinent committees.

VI

The IAGA, considering the importance of accurate knowledge of geomagnetic secular variation for the reductions necessary for magnetic surveys, especially in connection with the world magnetic survey, recommends that all magnetic observatories maintain their base-line values as accurately as possible, at least to the accuracy requested for the IGY program. Those magnetic observatories which have been in operation for many years are requested to continue their routine observations for as long as possible, in order to secure continuous series of records as geomagnetic variations.

VII

The IAGA considering that improved isomagnetic charts of the Indian Ocean are now possible because of the recent surveys by the nonmagnetic ship Zarya of the USSR, and that such charts could be improved further by inclusion of geomagnetic survey data obtained since 1920 on islands, and on other land areas adjacent to and bordering the Indian Ocean, recommends that such data be forwarded to Professor Poushkov as soon as possible.

VIII

IAGA stresses the importance of having correct measurements (by variographs) at some special 'variation repeat stations' for periods of several days. Such repeat stations are particularly needed in regions where the magnetic field is anomalous because of geological conditions, or where it is varying rapidly because of the nearness of the station to the auroral zone.

IX

The IAGA, considering the need for a universal agreement regarding the value of the gyromagnetic ratio of the proton for measurements of the geomagnetic field, *strongly recommends* that, pending the agreement and specification by an appropriate international scientific organization of a final value, all measurements of the geomagnetic field with a proton free-precession magnetometer, using pure water as the proton sample, shall be based on the following value of the gyromagnetic ratio:

$$2.67513 \times 10^4 \text{ radians/gauss, second}$$

X

The IAGA, appreciating the excellent series of geomagnetic Q-indices provided by a number of observatories, *recommends* that other polar observatories scale Q-indices at least for a limited number of days (about 110) to be selected from the IGY period by the Committee on magnetic activity.

XI

After taking into consideration the usefulness of the resolutions adopted by Committee No. 10, which follow the conclusions on the study of

short-term magnetic and telluric variations reached by the Utrecht Symposium of September 1959, the IAGA has adopted these resolutions, and requests that observatories comply with them.

The AIGA *recommends* that observatories situated in the equatorial zone and in polar regions undertake the installation of instruments capable of recording very brief pulses.

In order to obtain the most homogeneous results possible, the AIGA *recommends* that the greatest uniformity be obtained in the following parameters: a) rates of propagation; b) adequate sensitivities for bringing into prominence trains of pulses; c) periods of simultaneous recording when continuous recording for 24-hour periods is impossible.

The AIGA *recommends* also that Committee No. 10 determine the most important geographic gaps in the distribution of stations capable of recording these pulses. It also requests that the IUGG make recommendations to the various countries for organizing such observations.

The AIGA *recommends*, for the next Assembly of the Union, the organization of a Symposium devoted to the study of short-term magnetic and telluric variations and particularly of pulses lasting less than 20 seconds.

XII

The IAGA, aware of the fact that the work of the World Data Centers for geomagnetism established for the IGY must necessarily continue for a considerable time in order to complete the collection of data for the IGY/IGC period, and realizing the need for an interchange system by which geomagnetic data, for the years following the IGY/IGC period may also be made readily available to investigators, *urges* that all observatories continue to supply geomagnetic data for the WDC until the end of 1965, if possible on the same scale as adopted for the IGY/IGC period.

Besides the four symposia presented at the Helsinki meeting, a special symposium on Aeronomy was held at Copenhagen, July 19–22; a report on this follows the report on the Helsinki meeting.

Sessional Meetings

Committee 1

At a meeting held on July 27, the following recommendations were made: (a) that Committee 4 (Secular Variation and Paleomagnetism) accept responsibility for publishing observatory annual means; (b) that all observatories continue submitting standard and rapid-run magnetograms to WDC's; (c) that the next committee should circularize observatories in favor of adding gamma scale values on D-grams, and also that historical tables of annual mean values should be published.

Committees 2 and 3

D. M. Packer (*USA*) reported on a flight of a rocket by the Naval Research Laboratory and on the airglow heights that were measured. The results indicate that all of the oxygen covariant group, including the green line, O_4 emissions, and the continuum, arise from a common altitude centered around 95 to 100 km. The reported height for OH, centered about 80 to 85 km, would give a lower spectroscopic temperature than has been generally reported in the literature for temperate latitudes, and this discrepancy is not yet reconciled.

G. Kvifte (*Norway*) and *L. Wallace* (*USA*) reported on rotational temperatures of OH. Many of the rotational temperatures that have been published are about 10% too high. Correcting these values, Kvifte finds fair evidence for a latitude variation of temperature ranging from 220° K at middle latitudes (up to 60°N) and then rising to 300° K in the polar regions. Wallace argued that the agreement of rotational temperatures from different vibrational levels is strong evidence that these temperatures refer to the kinetic temperature in the atmospheric region of excitation. He also established that the seasonal variation in this temperature for middle latitudes has an amplitude not exceeding 30° K, but that even this small variation seems to be in phase with a larger seasonal variation found at 62° N by Jarin. Kvifte further discussed the relative populations of the OH vibrational levels, a subject that has some bearing on the excitation mechanism and has application to a prediction of OH intensities in the far infrared. Apparently the assumption that only the ninth vibrational level is excited directly by the air-

glow chemical reaction has often been made without any particular justification and ought to be abandoned in favor of more uniform excitation.

C. A. Barth (*USA*) has measured reaction rates for oxygen association. He announced that the Chapman reaction for the green line, in which O is a third body and absorbs the association energy of O + O, proceeds far too slowly to give the nightglow emission (see below). The rate coefficients for three-body formation of O_2 and of NO are in good agreement with the values previously adopted by Nicolet and others.

Mme. A. Vassy (*France*) reported a temperature of 170° K from interferometer measurements of the width of the green line in the airglow at Tamanressett (21° N). This is slightly lower than most values previously reported at higher latitudes.

T. N. Davis (*USA*) and *D. S. Kimball* (*USA*) summarized an analysis of IGY all-sky photographs in Alaska and their bearing on auroral morphology. *D. Barbier* (*France*) spoke on his photometric studies of the large, faint, stable arcs, which appear to be auroral in character, that he has observed in the red oxygen line in France. This line is at least 50 times as strong as the green line in these arcs, which have also been studied by Roach and, in the southern hemisphere, by Duncan.

R. A. Young (*USA*) and *K. C. Clark* (*USA*) discussed the laboratory production of the auroral green line (5577), and *W. T. Schade* and *J. Kaplan* discussed OI 5577 in afterglow spectra. Both of these papers, as well as one by Baron, gave limiting numerical values for the rate coefficient of the reaction that has long been associated with the emission of 5577 in the upper atmosphere:

$$O + O + O \rightarrow O_2 + O \quad (8)$$

The upper limit values of the rate coefficients, K, given by the three sets of investigators and the predicted upper atmosphere intensities of 5577, are reported in the table below.

The rate coefficients from all three laboratory experiments indicate that the reaction contributes insignificantly to the observed 5577 night airglow.

Two papers were concerned with detailed studies of auroras at College, Alaska. *M. H. Rees* (*USA*) and *C. Deehr* reported on a relatively stable red (6300) arc which moved from the northern to the southern part of the sky during the early evening of November 27, 1959. Observations from two stations placed the height near 350 km. The arc preceded general auroral activity in which the green line was a prominent feature. A red arc was observed at stations as far south as Sacramento Peak, New Mexico, during the same night. Whether or not the two arcs are associated is not known.

Investigators	*K*	*Q predicted in Rayleighs*	*Q median (observed) in night airglow*
Barth	$<<10^{-34}$	$<<2$	250
Young and Clark	$<10^{-34}$	<2	
Schade and Kaplan	$<10^{-33}$	<0.002	

A paper by *K. C. Clark* (*USA*) discussed the spectrum of the aurora of February 11, 1958, which was also rich in 6300 light. Time resolved spectra gave a spectroscopic history of the aurora during the night.

A paper on *The space-time variations of hydrogen emission from spectra of aurorae and their connection with magnetic disturbances* was read in abstract on behalf of *L. S. Evlashin* (*USSR*). The author based his study on 7000 spectra obtained at Murmansk during two winters, 1957–58 and 1958–59. The hydrogen lines H_α and H_β were studied especially with respect to magnetic activity with the conclusion that their presence is favored by a quiet magnetic field.

William G. Fastie (*USA*) and *Thomas P. Markham* reported the results of successful observations from a rocket of an aurora in the spectral region 1200A to 3200A. The atomic oxygen line at 2972 was identified as well as a number of Vegard-Kaplan bands. Lyman alpha was not observed.

P. A. Forsyth (*Canada*) discussed newer radio means of observing ionization associated with aurora, notably by means of bistatic radio systems. The new techniques showed a more direct correspondence between the optical and radio aurora. Future studies should help to resolve the question as to whether or not the radio au-

rora and the optical aurora are manifestations of the same phenomenon or are two quite distinct auroral processes.

K. Bullough discussed radio-echo observations of the aurora on 73 Mc with a rotating antenna from Dumont D'arville, Adelie Land (140° E, 66° 40′ S, geomagnetic latiude 76°). This base is close to the magnetic dip pole. Two reflecting regions were obtained, the inner one from azimuths of approximately 90° to 180°, the outer one from 270° to 350°; in the area 0° to 90° the two zones seemed to merge. The inner zone was associated with quiet magnetic conditions, K figures of 0-3, whereas the outer zone was associated with disturbances, $Kp \geq 4$.

S. A. Korff (*USA*) described ionizing radiation at 40 km during an auroral display of September 4, 1959. Cosmic-ray neutrons of energy $\geq$2.5 Mev were being measured. The system was such that single events would not be counted. When the aurora was optically brightest at about 0340 UT, the counter became saturated. The probable cause was a flux of high-energy protons with the Störmer cutoff not limiting the received energies.

Harold Leinbach (*USA*) discussed observations of polar cap ionospheric absorption events by 27.6 Mc cosmic noise absorption techniques at Barrow, College, and Farewell, Alaska. Four of the 27 events since May 1957 were shown in detail. In each case, after the solar flare the absorption increased up to the time of the magnetic storm and then absorption again decreased. Some possible mechanisms were suggested for trapping the particles responsible for these polar cap absorption events.

John R. Spreiter (*USA*) of NASA discussed a theory of elongated irregularities in the polar ionosphere. They were considered to be produced by the electric field generated by irregularities in the winds in the dynamo region.

H. K. Sen and *A. A. Wyller* (*USA*) extended the Appleton-Hartree formula utilizing a generalized conductivity tensor for the Lorentz gas to determine the refractive index. The elements of the generalized conductivity tensor were integrals involving the electronic velocity distribution function.

J. Baldwin and *T. R. Kaiser* (*England*) presented a means of studying non-deviative absorption in the D region during sudden ionospheric disturbances by changes in the rate of radio echoes from meteors as observed on 17 Mc. These meteors are of the 11th magnitude at just below 100 km. The rate suddenly decreases with the solar flare, and then gradually recovers. It was noted that attenuation increased with decreasing elevation. A two-frequency experiment is being planned to deduce the absorption more exactly.

The anomalous ionospheric absorption in winter days was the subject of a paper by *M. Bossolasco* (*Italy*) and *A. Elena*. Utilizing three indices—the mean value of absorption index A on 3 Mc at 1100, 1200, and 1300 LMT, the mean values of f_{min} at Genoa-Monte Capellino for those hours, and the mean intensity of WWV 15 Mc signals at Genoa, demonstrated that they—the winter anomaly was for January-February 1959—extended as far south as Genoa. In discussion, *J. Gregory* (*New Zealand*) stated he believes turbulent transport in mesosphere brings in the electrons that would explain the anomaly. *W. Dieminger* (*Germany*) confirmed the existence of the winter anomaly but limited to the mid-latitude belts; for example, the anomaly was not found at Tsumeb near the equator.

J. Tuominen (*Finland*) reviewed the paper 'On the rate of scintillation of Cassiopeia A on 45 Mc/s' by J. Tuominen, E. Kataja, and J. Riihimaa, An. Acad. Scient. Fennicae, A.VI 62, 1, 1960. From the scintillation measurements, if the producing layer in the ionosphere is at 300 km, an average ionospheric wind to the east at 15 km/hr is indicated.

Radio observations of ionospheric disturbance by back scatter at 17 Mc from Sheffield, England, on three azimuths was the subject of a paper by *J. Baldwin* and *T. R. Kaiser*. *F*-layer scatter was found at long range with fast fading. Maximum occurrence was at 0000 UT and was present almost 100% of the time in winter and 40% in summer. It was in agreement with occurrence of *F* spread at Iceland. Westward movements of 100 m/sec occurred before midnight, eastward afterward. The *F*-layer scatter correlated with Kp, the speed of motion increasing as Kp increased; for $Kp > 5$ the speed approached 11 m/sec. The *E*-layer scatter was associated with auroral disturbances. Fifty per cent of the aurora were accompanied by slow-fading spread echoes from *Es*. Diffuse echoes occurred in the evening, and discrete echoes late

at night and in early morning. It had a slow drift speed and occurred when *Kp* was low. Following strong aurora, the *F*-layer ground scatter was anomalous, being either absent or at extremely long range.

K. Bibl (*Germany*) was concerned with dynamic characteristics of the ionosphere and their coherency with the local and planetary magnetic index. At Freiburg the ionosonde technique first developed by Nagata has been in operation for a year. MUF, minimum height of *F* layer, and top frequency of the *E* layer, are registered directly against time. Four indices have been developed: *U*, the variations of the MUF curve; *H*, the variations of the height of the lower border of the *F* region; *E*, the number of events and maximum frequency of *Es*, and the local *K* or *Kp*. By a method of partial correlations, the interrelationships of these indices can be investigated. For example, it was found that there is a preference for *Es* to occur on magnetically quiet days.

N. P. Benkova (*USSR*) described some recent Russian work in ionospheric absorption and ionospheric disturbances. The absorption studies were made at Dickson Island in the auroral zone for frequencies between 2.2 and 3.2 Mc/s. The maximum absorption was observed before noon, six hours before the diurnal maximum of magnetic activity. Seasonally, the maximum absorption occurred near the equinoxes, with greater absorption in summer than in winter, in good agreement with the seasonal variations in magnetic activity. In another area, variations in the critical frequency of the *F*2 region were compared with magnetic activity. Positive values of $\Delta F_2 F_2$, the deviation of critical frequency from its average value, were not associated with magnetic activity at middle latitudes, but large negative values tended to occur on magnetically disturbed days at middle and high latitudes.

W. K. Kalmann discussed atmospheric parameters derived from satellite orbital decay and from rocks, and emphasized the existence of an 11-year cycle in atmospheric densities at ionospheric levels.

H. K. Paetzold (*Germany*) discussed density data obtained from satellites, and described a diurnal density variation of about a factor of ten at an altitude of 700 km and above; he also showed that a yearly variation amounting to a factor of 1.6 has occurred for three successive years, with a distinct minimum in June, July, and August. *R. A. Helliwell* (*USA*) stated that radio whistler data gave similar results, with a distinct minimum around July; the effect has been found in data from several years.

M. Nicolet (*Belgium*) presented a discussion on atmospheric data obtained from satellites, and emphasized that the scale height gradient in the ionosphere cannot increase with height because of the physics of atmospheric structure and the heating process.

T. E. Van Zandt (*USA*) discussed ionospheric theory, and indicated that values for electron production and loss, too small by about a factor of ten, have been used in the past; the error is due to the difficulty in estimating the rate of electron loss from diurnal variation. He also suggested that the low latitude red arcs in the night airglow can be explained in terms of ionospheric cooling and the collapse of the electron ion cloud that is normally present above the *F*2 maximum.

F. S. Johnson (*USA*) described a mechanism of heat transport by mass motion that is important in producing pressure equalization near 200-km altitude. The mechanism limits diurnal changes of atmospheric density at 200 km and above to the values obtained from satellite orbital decay; without a mechanism for horizontal heat transfer, much larger diurnal variations would be expected.

W. B. Hansen (*USA*) discussed the conditions that limit the electron temperature in the ionosphere, and concluded that the electrons and neutral gas must have essentially the same temperature, except in the *F*1 region, where the electron temperature may be twice as large as the neutral-gas temperature.

W. N. Hess (*USA*) described the contribution to the Van Allen radiation belt from neutrons leaking from the Earth's atmosphere. This source appears adequate for all except the extreme outermost portion of the belt, where the observed belt includes a soft electron component that cannot be explained on the basis of neutron decay; it was suggested that this component may originate from auroral activity.

A. J. Dessler (*USA*) described how the relative minimum observed in the electron belt can be caused by the anomalously weak magnetic field near South Africa; the exploration requires that the source of electrons be neutron decay,

and calculations based on the neutron decay source are in quantitative agreement with the observations.

C. P. Sonnet (*USA*) discussed magnetic field data obtained principally in Pioneer V, although some data from Pioneer 1 and Explorer VI were also described. The magnetic observations from Explorer VI indicate the presence of a ring current at a distance of 10 earth radii from the Earth. In the vicinity of 13 earth radii, large amplitude waves were observed, with disturbance amplitudes as much as 10 times the average magnetic field; these disturbances could be seen as close to the Earth as 3.7 earth radii, although the logarithmic response of the magnetic detector made it difficult to observe the variations in this region where the magnetic field is relatively much stronger. In Pioneer V, a magnetic field perpendicular to the plane of the ecliptic was observed; the average magnitude was 2.5 gammas. Variations in the magnetic field were observed that agreed well with magnetic disturbances observed on the ground; the magnitude of the effect on the ground was about seven times larger than that in the vehicle.

Committee 4

T. Nagata (*Japan*) and *L. Slaucitajs* (*Argentina*) reported the existence of a marked positive isoporic focus in western Antarctica for both the vertical component and the total field. At the center of the focus the rate of change is 200 gammas/year which is greater than any other place on the Earth.

T. Rikitake (*Japan*), *J. Mathews*, and *F. Lowes* (*Gt Britain*) discussed the two-disc dynamo model for the Earth's magnetic field. Solutions of Rikitake's equations have been accomplished by analog and digital computers. It was shown that the solutions are quite unstable, and that the oscillating dynamo currents reverse periodically or aperidically. The exact regimen of reversals depends on initial conditions, and any sequence apparently may be achieved. The general dynamo theory may, therefore, easily account for the observed paleomagnetic reversals.

K. M. Creer (*Gt Britain*) reported on low temperature studies of typical red sandstones. It appears that much of the magnetic material present in these rocks is in the superparamagnetic state, that is, the ferromagnetic grains are too small to have their directions of magnetization fixed, and only a few per cent give rise to the natural remanent magnetization.

Several new paleomagnetic virtual geomagnetic poles were presented for Antarctic, North American, and, especially, Russian rocks. Discussions of these, and of previously determined poles, indicated that there is still disagreement as to whether continental drift has taken place or not.

Committee 5
(Combined with Symposium: World Magnetic Survey)

N. Poushkov (*USSR*) reported for *M. M. Ivanov* that during the IGY the non-magnetic ship *Zarya* travelled more than 47,000 miles in the Atlantic, Pacific, and Indian Oceans, and the Mediterranian Sea. It employed fluxgate magnetometers on a gyro stabilized platform to measure X, Y, and Z, and a proton instrument for F. A gyro compass was used to help obtain the declination. Differences between the declination obtained by the *Zarya* in 1959 and the *Carnegie* in 1910-12 were shown. He compared *Zarya* observations in the Southeast Atlantic Ocean and Indian Ocean with world magnetic charts made by the Hydrographic Office and the British Admiralty. Some D readings varied from 2° to 6°, and from ± 500 in F. He reported good correlation with F profiles and bottom topography, particularly in the North Atlantic, over the Mid-Atlantic Ridge and sea mounts. Future voyages are planned for the North Pacific, and later for the Central and South Pacific.

B. C. Byrnes (*USA*) reviewed the organization, plan, and progress of the United States Navy, Hydrographic Office airborne geomagnetic survey, Project MAGNET. The survey constitutes more than 600,000 track miles, of which about 20 per cent has been completed. World-wide operations began in the fall of 1959. The major portion will be completed early in 1964, in time to permit incorporation of data in epoch 1965 World charts of all magnetic elements. Project MAGNET provides essentially continuous measure of all magnetic elements. Cosmic-ray (neutron) measurements are being made also on one of the two MAGNET survey aircraft. Other geophysical measurements, such as gravity, will also be incorporated in the airborne survey program, when practicable. Prob-

able errors of observations under good survey conditions are as follows:

Total field (F) ± 15 gammas
Magnetic heading (MH), inclination (I), celestial relative bearing (RB) ± 0.1°
Greenwich mean time (GMT) ± 1 second
Navigation (geographic position) ± 3 miles

The estimated probable errors in declination (D) and horizontal (H) and vertical (Z) intensities, which are computed from the above observations, are of the order of ±0.1° to ± 0.2° for D and 60 gammas for H and Z. The above results are being met or exceeded on recent surveys flights. Project MAGNET is a permanent and continuing program. Data are provided in tabular form and on punched cards.

P. H. Serson (*Canada*) compared the operation and accuracy of United States and Canadian airborne magnetometers, and the advantages and disadvantages of each. The Canadian magnetometer employs detecting elements mounted on a gyro-stabilized platform to determine the magnetic components continuously. He also presented a method for smoothing data in making charts so that the probable error for the chart can be specified.

J. F. Heppner (*USA*) described magnetic measurements made with proton instrument on VANGUARD III. He compared results obtained with Finch and Leston coefficients, with Jensen and Whitaker coefficients based on U. S. Navy Hydrographic Office charts, and Jensen and Whitaker coefficients based on Russian charts. The experimental values compared best with the last-named calculations. The computed fields are within one per cent of the experimental data. He noted that higher order harmonic terms may still be important in the representation of the field. He described graphics of measured field, from Vanguard III, minus computed field, based on weekly and monthly averages. He indicated that discontinuities may be due to Van Allen radiation belts. Measurements discussed were largely those made over California, Georgia, Cuba, Antigua Island, Ecuador, Peru, Chile, and Australia.

N. Poushkov (*USSR*) described a cosmic rocket magnetic experiment. Perturbations of varying amplitudes ranging from 200 to 800 gammas, have been found at approximately 20,000 km. The Moon rocket experiment indicated that the magnetic field was not increasing as the rocket approached the Moon. The field was less than 100 gammas at 50,000 km from the Moon's surface.

Committee 6

Papers extending the knowledge of lunar tidal effects on the ionospheric layers were presented by Benkova and Zagulyaeva, and by Bossolasco and Elena. Cain's analysis of 50 years of Sitka magnetic data showed the difficulties encountered at a sub-auroral zone station, where the lunar effects must be separated from other features of large magnetic disturbance. Herrinck raised the question as to whether or not some of the analysis techniques should be revised for a more accurate determination of the amplitudes of lunar effects. Schneider's analysis of magnetic data indicated that lunar distance effects accounted for about 20% of the half-daily lunar wave and increased with sunspot number; he showed also that the mean daily and half-daily waves contained a clear quarter-monthly oscillation, which had not previously been recognized and could probably account for some of the scatter in previous analyses.

Committee 7

Chairman *V. Laursen* (*Denmark*) stated that the question had arisen as to the desirability of transferring the center of the intercomparison program away from Rude Skov to some other observatory because Rude Skov was not equipped with nuclear precession magnetometers as standard intensity instruments, and therefore there might be some question regarding the reliability of the standard. The assembly then expressed full confidence in Rude Skov's standards and voted to keep the intercomparison headquarters at Rude Skov for at least the next triennium.

Following the Committee report and discussion, one paper was presented by *Asger Lundbak* (*Denmark*), on comparison of several observatories by studies of 'momentary values'; differences of secular change as well as wandering of baseline values were detected by comparing simultaneous values during the quieter periods of night.

Committee 8

J. H. Nelson (*USA*) proposed the adoption of a resolution specifying a definite value of the

gyromagnetic ratio of the proton for use in all geomagnetic work, pending the specification of an international value (perhaps in five or ten years) by whatever international authority—such as the International Bureau of Weights and Measures, or other—would be appropriate for this selection.

The value adopted was:

$$2.67513 \times 10^4 \text{ radians/gauss second}$$

B. M. Yanovsky (*USSR*) reported that two measurements made in USSR in 1960 agreed very closely with the above value, which was determined in 1958 by Driscoll and Bender of the U. S. National Bureau of Standards. In fact, one of the Russian values was identical and the other differed by only 2 units in the last figure.

A. J. Dessler (*USA*) gave a paper for *M. E. Packard* (*USA*) which stated that the proton-precession magnetometer was better for observatory standard measurements than alkali-vapor instruments because of a small orientation effect on the values measured by the latter.

L. R. Alldredge (*USA*) presented a proposal for an 'automatic' magnetic observatory to produce various kinds of statistical results with fully automatic equipment employing a proton precession magnetometer.

J. H. Nelson (*USA*) described the results of a comparison at the Fredericksburg Magnetic Observatory between the proton vector magnetometer and conventional instruments. A significant trend is noted in the plans of a number of countries to adopt the proton magnetometer as primary intensity-measuring equipment, not only for total field, but also for components. Japan and USSR described equipment now being used, and Canada has just built another type of vector magnetometer, using Serson's method of measuring components.

Committee 9

The session opened with discussions by *J. Bartels* (*Germany*), *Father Mayaud* (*France*) and *Father Cardus* (*Spain*) of the proper determination and use of the three-hour K and Kp indices of geomagnetic activity. These indices, for which tables are available dating since 1933, continue to be very useful in many fields related to geomagnetism, but it must be recognized that the 'planetary index' Kp is derived from, and is applicable principally to, the latitudes between the auroral zone and the equatorial electrojet. Inside the auroral zone, the disturbance phenomena are too complex to be represented by a single planetary index, whereas at the equator the index is useful chiefly during large disturbances, when the 'normal' or 'quiet' solar and lunar variations form only a small part of the total disturbance field. Additional stations established in the equatorial belt during and after the IGY are now adding materially to knowledge of the phenomena in this region.

Matsushita's work on the seasonal variation of Sq (based on quiet days only) indicates that the center of this current system shifts from higher latitudes in summer to lower latitudes in winter. Veldkamp's work on SFE's indicates a similar seasonal trend. This trend, which at present seems quite definite, differs from that suggested in many earlier studies.

The existence of an inner auroral zone, or an inner ring of magnetic disturbance, is confirmed further by the work of Whitham, Loomer, and Niblett and of Nikolsky and Senko, but at present the data are not entirely consistent with theoretical predictions such as those of Alfven or Nikolsky. The changes of average diurnal patterns of disturbance with increasing geomagnetic latitude inside the auroral zone seem well established. An apparent bifurcation of the main auroral zone, indicated in the Canadian data, will be of considerable theoretical interest if it is confirmed at other longitudes. The work of Milyaev suggests that the simple picture of the auroral zone currents being closed by a unidirectional flow across the polar cap may also need modification.

D. H. McIntosh (*Scotland*) showed that the twice-yearly maxima of magnetic disturbance occur very close to the equinoxes and not at times about two weeks prior to the equinoxes, as would be required by the 'axial' theory of annual variation. The phenomenon arises from the systematic, annual variation of the angle between the Earth's magnetic axis and the Sun-Earth line, but the mechanism is not fully understood. The annual component of the magnetic disturbance, with a maximum in summer and a minimum in winter, is shown in the weaker magnetic disturbances, a point which also appears in the work of Afanaseyeva.

An extension of previous theoretical studies of the magnetic effects of trapped particles,

based on reasonable distributions of particle density and pitch angles, was presented by *S. F. Singer* and *R. C. Wentworth* (*USA*). The longitudinal drift of particles with large pitch angles produces the most important effect and gives rise to a ring current that is concentrated toward the equatorial plane at 4 to 6 earth radii; diamagnetic effects were also considered. Lifetimes for these particles were estimated at one to two days, in agreement with the duration of the main phase of a magnetic storm. Diamagnetic effects of particles with small pitch angles penetrating near the Earth in the auroral zone were suggested as the cause of the reverse sudden commencement; lifetimes for these particles were estimated as a few hours. Calculations of magnetic effects at sea level had not been completed.

Average morphologies of 346 weak, moderate, and great magnetic storms having sudden commencements, classified according to average depression of H during the main phase, were determined by Sugiura and Chapman. In contrast to the GC (gradual commencement) storms, which show a preference for the equinoxes, the SC storms showed no definite seasonal variation, but increased with sunspot number. The D_{ST} (storm time) disturbance vectors were generally directed toward geomagnetic north; the maximum of D_{ST} (maximum depression of H) was reached at about 18 hours after the commencement (i.e., 18 hours storm time) for great storms, about 24 to 30 hours for moderate storms and greater than 30 for weak storms. The great storms also decayed more rapidly after the maximum was reached. DS (local time part of the disturbance vector) reached its maximum value about two or three hours after storm commencement, and its phase varied rapidly during the first few storm hours.

D. G. Knapp (*USA*) in a paper read by *L. R. Alldredge* (*USA*) compared the current vectors required to produce 'cusped bays' that occurred in the Arctic during large magnetic storms during the IGY with the current vectors associated with normal polar magnetic storms. These bays are characterized by large displacements in one or more of the magnetic components that are superposed on the main storms, last for ten minutes to an hour or more, and appear over a wide geographic range. The analysis indicates that the 'cusped bays' represent a modulation of the auroral zone electrojet on the main early-morning lobe, but large variations from the usual storm system may occur in the afternoon lobe of the electrojet, and in the return currents across the polar cap.

Kalinen estimated strength (magnetic moment) and radii of ring currents during magnetic storms, and suggested that the magnetic moment probably varied more from one storm to another than did the radius of the ring current.

Committee 10

The Committee 10 program was devoted to SFE's (solar flare effects), SSC's (storm sudden commencements) and 'Pulsations'. The first two categories are isolated events whose sources are known, at least qualitatively, and can readily be studied in detail.

J. Veldkamp (*Netherlands*) presented nine SFE current patterns for events occurring at different GMT times, computed from data from about 100 magnetic observatories. Significant differences from 'normal Sq' patterns (e.g., northern hemisphere currents often centered west, southern hemisphere currents centered east, of sub-solar point) suggested that the phase of the ionospheric 'winds' involved may differ from those in the E-region. A possible inference is that the SFE currents may flow chiefly in the D-region, where normal ionization is greatly enhanced by the solar flare radiation. The analysis of Cardus and Bolufer indicated a definite minimum in occurrence of SFE's at Tortosa in winter.

The exact time at which an SSC begins is an important but questionable point when theory is compared with the data. Selzer and Schlich found that the best agreement between different stations was obtained when the first movement in H (horizontal component), whether positive or negative, was taken at each station. Troitskaya reported that the 'microstructure' of SSC's on high speed records was greatly enhanced during daylight hours, which may further complicate the problem. Dessler reported that a negative correlation between amplitudes and rise times of SSC's would be theoretically expected from a model based on propagation at hydromagnetic wave velocity into the Earth's magnetic field. Matsushita found that SSC's in the USA, when classified into three groups ac-

cording to the nature of the movement in H, fell into three diffierent zones, defined as functions of local time and geomagnetic latitude of the observing station.

Most of the papers presented under Committee 10 were concerned with 'Pulsations,' which covers a wide variety of phenomena having periods from about 300 to 0.02 seconds; statistical analysis is required to determine the characteristics of these frequently occurring phenomena. Progress is being made in this important field, which is closely related to the hydromagnetic properties of the ionosphere, but the usual photographic recordings would require discouraging amounts of labor for the detailed analyses that are really needed.

The previously reported division of Pc's (continuous pulsations) into two frequency bands was discussed further and amplified by *J. A. Jacobs* (*Canada*) and *Sinno*, in their study of IGY data, and now seems generally accepted. Their conclusion that the longer period, or 70-second band, represents world-wide effects seems doubtful, however, in view of the reported diurnal variation in period at a single station determined from more sensitive records. *V. A. Troitskaya* (*USSR*) reports that Pc's tend to be daylight phenomena in polar regions, in agreement with the many results at middle latitudes, but that the equatorial results from Ghana, reported by Hutton, are anomolous, inasmuch as the maximum frequency there occurs at night. Jacobs and Sinno found that the maximum amplitudes for Pc's in the 20-second band occurred at middle latitudes, whereas maximum amplitudes in the 70-second band occurred in the auroral zone. Confirmation of these results from more sensitive records (which show many more Pc's) would be of great interest. The proper definition and characteristics of Pt's (trains of pulsations lasting less than a hour) still seem to be in question, so that comparisons of different results is difficult.

V. A. Troitskaya's discussion of pulsations having periods of 1 to 15 seconds was of interest, because little study has been made of them. The reported close relationship to magnetic disturbance and maximum occurrence between 23 and 08 hours local time is in general agreement with a previous study.

Troitskaya also reported pulsations of changing periods in the 1 to 15 second range called IDIP (intervals diminishing in period) during magnetic storms; it was suggested that these might be related to several other geophysical phenomena, but it appeared possible that the relationship might be the indirect common relationship to magnetic disturbance. *Duffus, Shand,* and *Wright* (*Canada*) presented a further discussion of their previously reported 'solar whistler's; it would appear that Troitskaya's IDIP's are the same, or a closely related, phenomenon. More extensive data on these phenomena could be very valuable.

E. Maple (*USA*) reported that thunderstorms produced most of the magnetic fluctuations between 1 and 50 c/s. An increase in signal strength observed at auroral-zone stations, and starting several hours prior to some large magnetic disturbances, was not attributable to thunderstorms. Signals were also observed from meteors in the 1 to 2 c/s band; these signals are unexplained, but the damped wavetrains observed suggest hydromagnetic resonance in the lower ionosphere. *Bonnefoy* and *Grenet* (*France*) discussed possible sources related to thunderstorms for the fluctuations above about 1 c/s.

Committee 11

Numerous papers outlining the history of geomagnetism and aeronomy in various countries were presented. Although this activity material is undoubtedly of value to geophysics, its nature is such that it contained no new research ideas that are not covered elsewhere; consequently, no details are reported here.

Symposium: Geophysical Aspects of Cosmic Rays

A. Ehmert (*Germany*) discussed the variation in the cosmic radiation spectrum during the solar cycle. He stated that the charge in the spectrum was similar to that which would be produced by an Earth potential varying between 1×10^9 and 2.5×10^9 volts and with an integral spectrum proportional to $E^{-1.5}$ for the low energy end of cosmic radiation in space. Also, results from Explorer VI show that the modulation of cosmic radiation observed at the Earth's surface is not produced near the Earth, as the same modulation was observed outside the geomagnetic field.

M. A. Pomerantz (*USA*) discussed an experiment performed to determine if any movement

of the cosmic radiation equator occurs during the solar cycle. A neutron monitor was installed on shipboard, and observations were made off the west coast of Africa and in the Indian Ocean. Within 1°, no charge was observed in the position of the cosmic radiation minimum over a two-year period. The positions of the minimum and of the dip equator were compared; there was essential agreement at 14°W, but at about 60°E the dip equator was found to be about 2° north of the cosmic radiation equator. *A. J. Dessler* (*USA*) commented that the integral invariant equator might be more significant than the dip equator, and that it would therefore be interesting to compare the positions of the cosmic radiation and integral invariant equators.

M. Kodama (*Japan*) in a paper read by *T. Obayashi*, indicated that the cosmic radiation minimum associated with the peak of the solar cycle was reached in January 1958 at low and middle latitudes, but at a later date at high latitudes. The long-term variations show this latitudinal dependence, but the short-term or transient variations do not.

H. Carmichael (*Canada*) presented results from the July 17, 1959, event which showed that cut-off rigidities calculated from an eccentric dipole did not agree well with observations made at a number of stations. Cut-off rigidities calculated by Rothwell's method from the local magnetic data for the observing stations showed discrepancies of about the same degree, but involving different stations. Cut-off rigidities calculated by the method of Quenby and Webber gave good agreement.

Results from the heavy nuclei detector in Explorer VII were discussed by *M. A. Pomerantz*. An ion chamber with three pulse height discriminators and with a polonium alpha source for calibration was used. Results from October 1959 showed an integral spectrum varying roughly in inverse proportion to the rigidity for $Z \geq 6$. It is expected that data will be gathered over a period of a year, and changes will be looked for. No data were obtained on May 4, 1960, because there was blackout on the 20 Mc/s transmission frequency, that was used.

V. Sarabhai (*India*) discussed the variations observed with meson telescopes inclined 45° to the vertical toward the east and the west. Variations corresponding to a local source of disturbance within the geomagnetic field showed up similarly on the two telescopes and were observed on magnetically disturbed days, and especially three to four days after the onset of cosmic-ray storms associated with magnetic storms having sudden commencements. Variations corresponding to an external source appeared with a 6-hour time-difference on the two telescopes, and were especially evident on magnetically quiet days; this corresponded to a source at an angle of $112° \pm 10°$ from the sun. Such an anistropy in the cosmic radiation flux might be produced by a solar beam of ionized matter with a frozen-in magnetic field.

D. C. Rose (*Canada*) discussed anistropy of cosmic radiation flux indicated by 12- and 24-hour periodicities in neutron monitor outputs. He felt that the 12-hour component was atmospheric in origin, and that the 24-hour component was real. Sarabhai felt that the 12-hour component was more dominant at the close of the last solar cycle (1949–1958) than now, that there is a 12-hour component which is not related to pressure, and that Rose's data may not show it because they were taken early in the solar cycle, when the morning maximum was nearly missing.

P. Meyer (*USA*) discussed results from the Chicago experiments in Pioneer V and Explorer VI. On September 3, 1959, solar flare protons were observed 20 to 30 minutes after a class 2 flare; this prompt arrival shows that disordered fields between the Sun and Earth cannot exceed 10^{-4} gauss; also, the tail of the pulse of protons shows that a storage mechanism exists characterized by a decay time varying as t^{-1} or $t^{-1.3}$. On four occasions in April and May 1960 increases in counting rate were observed in Pioneer V, again showing travel times within a factor of two of the straight-line travel time and storage for two or three days at some location not near the Earth. On March 27, 1960, a flux of 200-kv and above electrons, small compared to the Van Allen electron fluxes near the Earth, was observed in Pioneer V. A Forbush decrease was seen with full intensity in Explorer VI at a distance of about seven earth radii from the Earth, and it was also seen at a distance of 5.2×10^4 km in Pioneer V; this shows that the Forbush decrease is not an effect produced locally around the Earth.

D. D. Krasilnikov (*USSR*) summarized the past year's research on cosmic radiation in Russia. Observations of neutron flux at Yakutsk at several depths below ground were shown. Also, shown were recordings during the Forbush decrease of May 11, 1959, in which a relative decrease of 4.2% was observed at the surface, 3.1% at a depth of 7 m water equivalent, 2.7% at 20 m, and 1.3% at 60 m. The recoveries at the various depths showed different time dependence, four or five days at 60 m, six or seven days at 20 m, and eight or nine days at 7 m. Krasilnikov also presented a discussion of Dorman's ideas about solar corpuscular streams and their effect on modulating the cosmic radiation flux at the Earth, both on a diurnal scale and a 27-day scale.

T. Obayashi (*Japan*) discussed the low-energy cosmic radiation associated with solar flares, describing the control of their trajectories by nearly radially directed magnetic field lines from the Sun; although directed almost radially, the field lines are curved due to the Earth's rotation. Low-energy cosmic radiation from flares in the western half of the solar disk arrive at the Earth within an hour or less, inasmuch as the solar magnetic field lines passing near the Earth connect to that region of the Sun; radiation from flares in the eastern portion of the solar disk are delayed from five to as much as 20 hours, because they cannot move directly along magnetic field lines to the Earth. Obayashi feels that there may be some turbulence and scattering near the Sun. The delay time for magnetic storms is 20 to 50 hours, and there is no relation to the position of the flare on the Sun; the lower energy particles associated with the magnetic storm are so numerous that their total energy density exceeds that of the magnetic field, and hence they push the magnetic field aside and are not guided by it.

K. G. McCracken (*USA*) discussed the rise time and decay time for cosmic radiation associated with solar flares. The rise time and decay time were fast (~10 min) in 1960 and slow (~2 hr) in 1946. McCracken interpreted this in terms of a radially directed field extending out from the region of the flare, with disordered fields elsewhere in interplanetary space. The arrival of particles agreed better with a source displaced 75° to the west of the Sun, but in the plane of the ecliptic. In discussion following the paper, *A. J. Dessler* (*USA*) pointed out that the radially directed field had to exist prior to the flare in order to explain the arrival of particles at the Earth, and hence that it was necessary to assume that the radial field was a general feature, not one associated only with that sector of space over the flare.

S. F. Singer (*USA*) stated some conclusions reached on the basis of meson telescope data from the polar regions. The seasonal variation was observed to be large at both stations and out of phase; this is due to the peculiar structure of the polar atmosphere. The meson decrease at temperate latitudes during a Forbush event is less than the neutron flux decrease; a similar result was obtained at the polar stations. Increases in counting rate with solar flares were observed simultaneously at both poles, with the maximum about an hour after the flare. The May 4, 1960, event produced polar absorption and neutron flux increases at College Park, Banff, and Climax, and a neutron increase but no meson increase at Thule; from these data it is concluded that the spectrum of the enhanced cosmic radiation was very steep.

J. G. Roederer (*Argentina*) showed that the absorption length of the enhanced component of cosmic radiation can be obtained from neutron telescopes. The lower tray of counters shows a lesser increase than the upper tray, and from this Roederer calculated an absorption length of 93 ± 9 gm cm^{-2} for the additional radiation observed at Ellsworth on May 4, 1960. Roederer suggested building a neutron detector with four trays of counters to improve the resolution in determination of absorption length.

Symposium: World Magnetic Survey

(see under Committee 5)

Symposium: Problems of the High Atmosphere

E. Vassy (*France*) emphasized the present rapid evolution of facts and understanding concerning the circulatory behavior of the high atmosphere, an evolution brought on by the increased concentration of interest and the new probing techniques of balloons, rockets, and satellites.

Initial results of machine calculations of a simple model of circulation were presented by *R. J. Murgatroyd* (*Gr. Britain*) who fitted a

sufficient vertical and horizontal meridional circulation to produce the known temperature distributions and radiative sources and sinks. This simple overturning motion in the meridian plane can account for many of the major features of wind and temperature in the height range from 15 to 85 km. Results showing trajectories of air masses in summer and winter lead to the conclusions that the lower stratospheric air must have come up through the lower tropopause in the past two years and must be quite dry, and that debris from atomic expolsions should move up in high trajectories toward the poles. The next refinement of the model is expected to include horizontal eddy motion and its effects in the conservation of angular momentum.

Observations of circulation and temperatures at great heights were described by several investigators.

The studies of *G. Barbe* (*France*) included patterns of circulation over Europe during 1956–60. Although the evident separation of polar and subtropical jet streams in the springtime of 1959 was termed abnormal, it was pointed out in discussion that this could be a characteristic seasonal effect for Europe.

A detailed description of the reversals in horizontal components of stratospheric winds was given by *A. D. Belmont* (*USA*) who consolidated measurements from 30 radiosonde stations along the east and west coasts of North America. Average monthly charts of the meridian plane showed distributions in height and latitude of the statistical prevalence of east or west motion and the mean speeds. These illustrations showed the strong seasonal changes between the extremes of the prevalence of easterlies in June, above 15 to 12 km, at all latitudes, and of westerlies in January, except below 20 km and 20° latitude. Valid studies of vertical motions will require much more data.

W. G. Stroud (*USA*) described temperature measurements made by use of rocket grenades. About 35 rockets firings have been made over the past ten years from Fort Churchill, White Sands, and Guam. The precise timing of the propagation time of sound from periodic explosions at the rocket can be used up to heights of 95 km, and lead to calculated air temperatures of about ±2°C precision. Although the first emphasis has been on the summer-winter comparisons in temperature profiles, future work is intended to fill in details of seasonal changes.

S. Teweles (*USA*) described an example of very strong fluctuations of temperature and wind about 80 km above Fort Churchill, in substitution for his listed subject, now published. He also presented composite cross-sections from Alaska to Germany for both temperature and wind at heights up to 50 km; these demonstrated that each layer has its own circulation pattern, which is determined initially by interchange of energy with a lower level.

The importance of very small vertical wind components was emphasized by *H. Paetzold* (*Germany*) who related changes of the concentration and concentration gradient of ozone to vertical motions in the range of 20-km height.

These papers have shown that, although a great deal more is known about circulation in the lower mesosphere, the motions in the upper mesosphere, especially near the mesopause, are more violent and complicated than was thought at first.

B. Haurwitz (*USA*) discussed the semi-diurnal variation of winds in the 80-100 km region based upon the use of radio methods for the study of drift of ionized meteor trails. He quoted results from independent studies at Jodrell Bank (latitude 53°N) and at Adelaide, Australia latitude (35°S). A semi-diurnal term was found, the magnitude of which was much larger than that near the earth's surface. Although the results are definite, a significantly larger sample of data would be required in order to show details.

W. W. Kellogg (*USA*) reviewed current knowledge of dynamical conditions up to 120 km. He called attention to the winter warming near 80 km and speculated that this might be due to release of energy in the association of oxygen atoms into the molecule by way of the triple collision: $0 + 0 + M \rightarrow 0_2 + M + 5$ ev.

R. R. Rapp (*USA*) discussed the possibility that small particles might be trapped in the 80-km region, their downward movement being compensated by being caught in atmospheric turbulent regions.

J. Gregory (*New Zealand*) described ionosonde studies in New Zealand that indicate preferential turbulent regions at 55, 66, 74, and 85 km. The method of measurement refers to regions of physical size about 50 to 100 meters in size.

J. Blamont (*USA*) showed that, on the basis of six experiments with sodium ejected from rockets, there is a well-defined altitude (102 km) above which large-scale shears, but no significant turbulence, are present, and below which turbulence is pronounced, with no strong shears. He discussed the significance of the observations in terms of such turbulence criteria as the Reynolds number and the Richardson number.

T. R. Kaiser (*England*) discussed the technique of measuring wind velocities by radar reflection from meteor trails, and some results obtained at Manchester (53°N), Adelaide (35°S), and Moreson (68°S) He pointed out that it was possible to obtain only the mean radial wind vector averaged over a long time, and that the results hold only for the region near 90 km. The results suggest a prevailing wind pattern with high winds of about 50 km/sec at latitude 35°S, much weaker, winds near latitude 53°S, and a strong meridional component—away from the summer pole—at latitude 68°S. Consideration of the diurnal component in the winds also suggests that two cells exist; one of these is in middle latitudes, and the other is in high latitudes, again with Manchester as a sort of node.

K. Rawer (*Finland*) reported on the determination of ionospheric winds in the E region, as measured by observing the passage of characteristic patterns in ionospheric soundings echoes over a network of ground stations. This method measures velocities of ionospheric irregularities only. The results for stations at North latitudes 18°, 21°, 31°, 48°, and 53°N show that the circulatory pattern is extremely complex. He showed that there is a lunar tidal component in the winds, particularly for the 6-hour component.

V. H. Regener (*USA*) discussed a new method of measuring atmospheric ozone. It consists of pumping ozone past a solid sample of silica gel treated with aluminol, which fluoresces when exposed to ozone. A photomultiplier tube looks at the scintillator. The pump operates for 15 seconds of each minute; 15 seconds are devoted also to recording temperature and pressure, and 30 seconds to obtaining a reference zero for the photo current. Results obtained give ozone concentration from the ground to 35 km and reveal fine structure in the distribution of scale much less than one km.

S. I. Rasool (*France*) showed correlations he has found between solar activity and the height of the tropopause, the height increasing with sunspot number, and between magnetic storms and the amount of ozone in the ozonosphere.

Robert Karplus, W. E. Francis, and A. Dessler (*USA*) discussed a mechanism for explaining the increased atmospheric density during magnetic storms observed by satellites. They proposed that the heating is caused by the arrival of a hydromagnetic wave (amplitude $\sim 100\gamma$, period ~ 4 cps), which causes the ions in the E or F region to oscillate and thus to heat the atmosphere by collisions. They showed how these ideas are supported by the observation of giant micropulsations in the geomagnetic field of the right period during magnetic storms, and suggested that the phenomenon could account for a number of effects, including the red auroral arc observed by Roach and others.

Copenhagen Meeting: Symposium on Aeronomy

July 18–22, 1960

University of Copenhagen

Studiegarden, Studiestraede 6, Room A

Introduction

Preceding the General Assembly of IUGG, a special Symposium on Aeronomy was held at Copenhagen, July 19–22. The meeting was planned jointly by M. Nicolet, Chairman of Committee 3 of IAGA on *The High Atmosphere*, and Joseph Kaplan, President of IAGA. It comprised eight sessions of invited papers and

was attended by about 200 scientists. The sessions were organized as follows:

Subject	*Chairman*
1. Incoming Radiation	M. Nicolet
2. Atmospheric Composition and Densities	Whipple
3. Diffusion and the Exosphere	Robert Jastrow
4. Incoming Radiation (continued), Excitation, Dissociation, Recombination, and Attachment and Meteors	J. E. Blamont
5 and 6. Aurora and Airglow	C. T. Elvey
7. Geomagnetism and Aeronomy	J. Bartels
8. Recapitulation and Discussion	J. Bartels

E. Anderson, President of the Danish National Committee of Geodesy and Geophysics, as host to the Conference, welcomed the members, expressing the great interest of the Danish scientists in geophysical progress. J. Kaplan, (USA) President of IAGA, spoke of the great and rapid progress in our understanding of the Earth's exterior environment as a result of the IGY. This special meeting was necessary to cover the great developments in Aeronomy emergent from IGY measurements. Ideas were changing rapidly as a wide variety of observations were coming into focus.

Sessions

First Session: Incoming Radiation

R. Tousey (*USA*) showed magnificent examples of solar spectrograms taken from high altitude rockets, with spectral lines defined clearly down to a pair of lines near 500A, which were identified as the resonance lines of Si XII. Using spectral photometry, he has estimated the absolute radiation levels of the ultraviolet, and concludes that from 800–1500A the average level is 0.01 ergs cm^{-2} sec^{-1} A^{-1}, with a Lyman alpha peak >1.0 ergs cm^{-2} sec^{-1}, and reaching perhaps 6 ergs cm^{-2} sec^{-1}. One problem involved correction for water vapor absorption whose origin may be in either the spectrometer chamber or the vehicle. This correction can be estimated from laboratory measurements at various wavelengths. Tousey gave a preliminary summary of estimated radiation levels as corrected across the band, from data available to date, as follows:

Wavelength (A)	ergs cm^{-2} sec^{-1}
2000 ± 25	65
1950	55
1900	40
1850	30
1800	20
1750	10
1700	7.5
1650	(6)
1600	(5)
1500	(4.5)
1500	4
1450	1.5
1400	1
1350	0.6 + C II 0.4
1300	0.5
1250	0.5
1200	0.6 + Lyman alpha ~6.0
1150	0.3
1100	0.15
1050	0.1
1000	0.1
950	0.1
925–850	~0.8

Photometric measurements at shorter wavelengths require further work for definition. In the discussion, *H. E. Hinteregger* illustrated continuous telemetry of photoenergy versus wavelength by employing a scanning monochrometer. His results appear to augment those of Tousey, but cannot, of course, distinguish individual line emission.

Tousey showed that the following lines are prominent in the short U. V. range and can be distinguished:

910 (A)	C II (3)	630	V
830	O II, III	610, 625	Mg X doublet
790	S V, O IV	584	HE I
770, 780	Ne VIII	~500A	Si XII doublet

Hinteregger showed a spectral trace in which the He II 5304 line and the beginning of the He continuum can be distinguished.

R. W. Kreplin (*USA*) discussed the 2–8 and 8–20 A bands as seen from rockets with appropriate filters. He noted an increase in intensity of 39 and 45 times in the two bands, respectively, from 1953–1954 (sunspot minimum) to 1959 (sunspot maximum), and questioned whether terrestrial ionospheric or atmospheric excitation phenomena showed a similar maximum. The ratio of increase does not seem to be high in the 20–200 A range.

H. Friedman (*USA*) showed a rocket photograph of the Sun in the x-radiation regions, and a CaK spectroheliogram made on the same

day. The sources appear to be localized on the Sun's disc in active areas corresponding to calcium plages, and can be expected to vary enormously with solar activity.

Present quantitative knowledge of line structure in the solar emission represents a great advance, making possible estimates of photochemical processes in the high atmosphere as a consequence of absorption.

Second Session: Atmospheric Composition and Densities

C. A. Whitney (*USA*) discussed the techniques employed for the derivation of atmospheric densities from observations of satellites. At present the data have a resolving power of some 20°-40° of longitude along the orbit and about one-half to one day of time. The principal uncertainties are due to imperfect knowledge of (a) the efficiency of momentum transfer between the satellite and the atmosphere and (b) orientation and effective frontal area the of the non-spherical satellites. Electrical drag has been found to be trivial.

L. C. Jacchia (*USA*) presented a time-varying model for the atmospheric density in the region 180–700 km, as derived from satellite data. The principal features of this model are (a) the density is everywhere proportional to solar activity as indicated by centimeter noise emission, and (b) there exists a daytime "bulge" in the surfaces of equal density, displaced about 30° in longitude to the east of the sub-solar point. This diurnal bulge is barely perceptible at the 200-km level. Jacchia presented the explicit formulae describing the model, and demonstrated the high degree to which the model reproduces the apparently irregular satellite drag variations.

D. C. King-Hele (*Gt. Britain*) presented data from eight satellites whose orbital changes definitely indicate that atmospheric densities are greater on the daytime side of the Earth than on the night time side.

W. Priester (*Germany*) presented height profiles of atmospheric density as functions of solar activity, and longitudinal profiles of density at specified heights. These profiles are in essential agreement with Jacchia's results. Priester indicated that rocket and satellite density data can be reconciled through proper attention to solar activity.

C. Y. Johnson (*USA*) reviewed experimental attempts to determine atmospheric composition in the E and F layers through the use of mass-spectrometers. The three major constituents are NO, O, and O_2. The composition varies with local time and with height. No evidence of hydrogen was found, even though the instrument was capable of observing a threshold of 500 ions/cc.

Third Session: Diffusion and the Exosphere

P. Mange (*USA*) discussed the many experimental programs that are directly concerned with diffusive processes in the upper atmosphere. The mass spectrometer results have shown that the diffusive level for minor constitutents lies just above 100 km. The technique of releasing chemicals at high altitudes shows promise for determining the density, and perhaps even the temperature, of the atmosphere in regions where mixing effects can be neglected. Already quite reliable diffusion coefficients have been obtained for several of the alkali metals in the upper atmosphere.

Mange showed that there exist upper limits to the escape fluxes of H and He, provided by reasonable estimates of the concentrations of these elements at low altitudes, and that the maximum allowable flux for H is about one order of magnitude lower than the 10^8 atoms/cm²/sec ordinarily assumed.

He also discussed diffusive equilibrium. Mange showed that the scale heights for different ions in diffusive equilibrium depend strongly on the average ionic mass. The scale heights of H^+ and He^+ are negative in a predominantly O^+ ionosphere. Thus, in effect, the light ions float on the heavy ones and their number densities actually increase with altitude.

Mange showed the results of calculations for the diffusive redistribution of atomic nitrogen after darkness, and discussed the relationship of these calculations to the chemical composition of the atmosphere. He also presented curves showing the diffusive settling of calcium as a function of time, following its release in the atmosphere.

Finally, Mange presented a mathematical model for interpreting the latitudinal and vertical atmospheric thermal conductivity in terms of a wedge-shaped solid. This model

makes available mathematical solutions for the simple evaluation of the effect of auroral heating on the atmosphere as a whole, and for the diurnal temperature variations in the atmosphere.

V. C. A. Ferraro (*Gt. Britain*) reviewed the historical development of our understanding of the role of ion diffusion in the upper atmosphere since his original suggestions in 1945 that a neutral particle density of 10^{10} atoms/cm^3 was required to prevent the F_2 layer from diffusing away. He then presented a discussion of some recent work by Gliddon and Keadall, in which the effects of ion diffusion on the morphology of the F region were investigated quantitatively. In this work an isothermal atmosphere and a monochromatic ionizing radiation were assumed, together with a linear loss rate coefficient of the form suggested by Ratcliffe and his co-workers. Prof. Ferraro reported that the initial calculations, including diffusion, have shown satisfactory agreement with the observed F_2 layer time-and space-variations reported by Martyn.

S. F. Singer (*USA*) discussed the distribution of both neutral and charged particles in the exospheric region. The amount of hydrogen to be expected above the base of the exosphere is best determined by the highly resolved spectrum of the solar Lyman alpha line; from these data a concentration at the base of the exosphere of 10^4 hydrogen atoms cm^{-3} is obtained. The vertical distribution of hydrogen above this altitude is difficult to predict because of the escape flux and the lack of thermodynamic equilibrium. Figures were presented for the ballistic component of the hydrogen exosphere, consisting of particles connected to the base of the exosphere by ballistic orbits, and of the bound, or satellite, component, consisting of atoms simply orbiting the Earth. The presence or absence of the satellite component is not entirely clear, and Dr. Singer discussed the conditions bearing upon this problem.

The ionized component of the atmosphere above the base of the exosphere is affected by both the magnetic and gravitational fields. The vertical distribution of ions can be calculated from the hydrostatic equation, because there is no escape flux of protons, and also because frequent collisions in the exosphere assure thermodynamic equilibrium. The temperature is the same as that at the base of the exosphere. The question of co-rotation and its effect on the proton distribution was mentioned briefly.

From a sudden break in the intensity versus altitude curve, Dr. Singer inferred that a change in atmospheric composition from neutral to ionized atomic oxygen takes place at about 1500 km.

Fourth Session:
Incoming Radiation (continued)

H. Friedman (*USA*) reviewed the experimental data on the solar cycle variation in Lyman-α intensity. For the past four years the measured values cluster between 3 and 6 ergs/cm^2/sec. A solar disc photograph in Lyman-α (1959) showed that 80% of the emission came from the areas of Ca plage formations, 20% from the background. Since the plages almost disappear at solar minimum, at least a 4 to 1 reduction in Lyman-α intensity may be expected. An X-ray image of the sun obtained with a pinhole camera (1960) showed a similar detailed correlation with Ca plage formations. It appears that the sources of all solar ionizing radiations as well as the radio decimeter wavelengths are closely identified with plage areas.

It was suggested that resonant scattering of He II (304A) by singly ionized helium in interplanetary space may contribute a flux of between 10^{-3} and 10^{-2} erg/cm^2 sec upon the terrestrial atmosphere and provide an important source of nighttime F-region ionization.

A. Dalgarno (*Gt. Britain*) noted the distinction between processes of charge exchange and ion-atom interchange. Rate coefficients of the ion-atom interchanges

$$O^+ + N \rightarrow NO^+ + N$$
$$O^+ + O_2 \rightarrow O_2^+ + O$$

have been assumed to be as large as 10^{-9} cm^3/sec by many aeronomists. Quoting recent estimates by Nicolet and by Sayers, the rate coefficients are as slow as 10^{-13} or 10^{-11} cm^3/sec respectively.

The charge process

$$O^+ + H \rightarrow O + H^+$$

is extremely slow at thermal velocities. The estimated cross-section is 10^{-19} cm^2 and the process is therefore not important in the exosphere.

Experimental values for the dissociative recombination coefficients of N_2^+ are 4×10^{-7} and 2×10^{-7} cm³/sec at temperatures of 400°K and 2500°K, respectively. A less certain result is 3×10^{-7} cm³/sec for O_2^+ at 2400°K. It was noted in the subsequent discussion that rocket measurements of solar flux and *E*-region electron densities indicate an effective recombination coefficient of 4×10^{-8} cm³/sec in *E*-region.

An order of magnitude value for the dissociative recombination coefficient of NO^+ at 5000°K is 10^{-9} cm³/sec.

T. R. Kaiser (*Gt. Britain*) reviewed the various types of data from which meteor information is derived—visual, radio, rocket and satellite, accretion, atmospheric dust, and zodiacal light.

There is little difference in the flux magnitude distribution between showers and sporadic meteors.

Radio observations become incomplete for meteors fainter than 10th to 11th magnitude. At magnitudes above 20 the particles may be driven away by solar radiation pressure before they enter the Earth's atmosphere. Because there is very little change in gradient of the flux-magnitude curve below 11th magnitude, it is assumed that the curve may be extrapolated linearly to higher magnitudes. The extrapolated radio distribution falls well below the zodiacal light data and the results of rocket and satellite measurements. It is recognized that satellite data have been beset with difficulties that make it difficult to assess their true accuracy. On the other hand, there is no obvious reason to doubt the zodiacal light measurements.

Fifth and Sixth Sessions: Aurora and Airglow

J. W. Chamberlain (*USA*) summarized the average intensities of radiation from the airglow and aurora. Average values for airglow intensities are 250 R (Rayleighs) for the oxygen green line (5577A), 50 to 100 R for the oxygen red line (6300A), 200 R in winter and less than 30 R in summer for the sodium lines, 5 to 20 R for the hydrogen red line (6563A), 1.5 kR for the molecular oxygen atmospheric line (8645A), 430 R for that part of the molecular oxygen Hertzberg band system in the observable region, and 175 kR for the OH lines near 1.58 μ. These observed levels infer a total OH emission of perhaps 4500 kR; also, the O_2 atmospheric lines probably have a total emission of 8 to 30 kR, in which case, except for the OH lines, they would actually constitute the most intense night-sky emissions.

Intensities of auroral lines are more difficult to estimate. For an aurora of International Brightness Coefficient III, Chamberlain estimates the intensities of the strongest lines to be 100 kR for the oxygen green line, 50 kR for the oxygen red line, 100 kR for the $[NI]_2$ line (10400A), 200 kR for the N_2 first positive bands, 100 kR for the N_2 second positive bands, 150 kR for the N_2 Vegard-Kaplan bands, 165 kR for the N_2^+ first negative bands, 2500 kR for the N_2^+ Meinel bands, 400 kR for the O_2 atmospheric bands, and 1000 kR for the O_2 infrared atmospheric bands; also, when the hydrogen red line is visible, the intensity of the Lyman-α line is probably 100 kR. From the observed 100 kR intensity for the 3914A line of N_2^+, Chamberlain estimates ion production rate of 7×10^{13} ions sec^{-1} (cm² column)$^{-1}$, which infers an energy flux of 2.5×10^{14} ev/cm^{-2}/sec^{-1} or 400 ergs/cm²/sec. This figure is very interesting, because only 18 of the 400 ergs/cm²/sec can be accounted for in emission of observed lines; it is probable that an important part of the remaining energy goes into the Lyman-Beige-Hopfield lines in the vacuum ultraviolet. Further, an energy flux as large as 400 ergs/cm²/sec cannot be expected to be carried by protons if the hydrogen red line intensity remains below 10 kR, as observed. As electric discharge has been excluded as a possibility for auroral excitation, electron bombardment remains the only possible source for auroral excitation. An energy flow of 400 ergs/cm²/sec into an aurora is a significant heat source; the rate of heat influx is sufficient to double the average energy per atmospheric particle above 100 km in about 13^3 seconds; such a heating rate is important but is much smaller than has been supposed by some.

To estimate the over-all importance of particle bombardment in polar heating, Chamberlain considered an average auroral activity of International Brightness Coefficient I over the entire polar area; this would supply energy at a rate which would double the atmospheric energy over 100 km in one day; this is comparable to the thermal relaxation time of the atmosphere

above 100 km. Hence such heating would be significant but only comparable to the normal heating of the upper atmosphere at lower latitudes.

W. G. Fastie (*USA*) described an Ebert ultraviolet spectrograph that was flown into a weak auroral cloud at Fort Churchill. The wavelength range was 1100A to 3500A, and the field of view was split so that one-half the field was along the rocket axis while the other half was perpendicular to the rocket axis; the spin of the rocket provided a scanning of the sky. Also, two photometers were provided to monitor the 3914A line. The strongest emissions observed were in the 1200 to 1400A region of the spectrum, and five lines of the Lyman-Beige-Hopfield band system were identified. Other unidentified lines were found near 2500A; however, the analysis is still in a very preliminary state. Lyman-α emission was apparently not observed.

M. H. Rees (*USA*) mentioned the observation of hydrogen red line emission as bright as 500 R in arcs that precede bright aurora.

D. M. Packer (*USA*) discussed the altitudes of airglow emissions, primarily on the basis of measurements made in rockets. The 5577A line was observed in several flights to have its maximum intensity at an altitude of 97 km, and 85% of the emission was between 85 and 105 km. The 2500A to 2950A region was observed in November 1959 to have a broad maximum from 65 to 85 km, with the emission confined largely between the limits of 40 and 110 km. On the same flight, the 7619A line was observed to have its maximum intensity at 75 km, with the emission occurring almost entirely between 40 and 120 km. The 6300A line is observed in rockets to be emitted above an altitude of 160 km, with no indication of how far above that altitude. The sodium doublet had its maximum emission near 85 km on December 12, 1955, with the limits of the emitting layer at 70 and 100 km; on November 6, 1959, the maximum emission was at 91 km, with the limits on the emitting layer at 70 and 110 km. The OH line at 7274A was observed to have a maximum at 85 km, with 90% of the emission between 72 and 95 km; the 7400 to 10200A region had its maximum near 90 km and a lower limit near 80 km. An instrument failure prevented observation of the upper limit of the emitting layer. Background measurements made in the continuum emission region near 5400A have indicated maximum emission near 104 km.

Mme. E. J. Vassy (*France*) commented that the observations on the green line are not consistent with a single emitting layer. Packer indicated that one rocket flight gave some indication of a feebly emitting cloud somewhere above the main layer of emission for the green line.

D. M. Hunter (*Canada*) discussed the temperture data available from night-sky and auroral observations. Although data can be obtained from a number of lines, principally from the Doppler profiles or from the rotational structure, the temperature values apparently are not accurate enough to add much to our knowledge of the temperature structure of the upper atmosphere. However, the temperatures obtained from these observations seem to agree fairly satisfactorily with present ideas of atmosphere structure. Two exceptions may be noted. The rotational structure of the first negative system of N_2^+ indicates a temperature high in the ionosphere of 2200°K, which is about 50% greater than temperatures indicated by satellite orbital decay data; also, the OH band system indicates temperatures that are significantly higher than the temperature of the atmospheric region in which the radiation originates, although the altitude region concerned in this case is near 85 km.

F. E. Roach (*USA*) reviewed the data on oxygen green-line emissions in the night sky. The green line emission is frequently attributed to the three-body recombination process.

$$O + O + O \rightarrow O_2 + O\ (^1S).$$

He pointed out that this reaction can explain the intensity of the green-line emission only if the rate coefficient is larger than 10^{-34} cm^6 sec^{-1}.

R. Young (*USA*) then described a set of measurements in which a value of less than 10^{-32}/cm^6/sec^{-1} was obtained for the rate coefficient.

C. A. Barth (*USA*) described an entirely different type of measurement in which a value of 10^{-33}/cm^6/sec^{-1} was obtained. This seemed to make clear that the three-body recombination process listed above cannot account for the

emission of the oxygen green line in the night airglow.

D. Barbier (*France*) reviewed the data on the oxygen red-line emission in the night airglow. A weak minimum is apparent during the night. Also, there is a variation with solar cycle, with greater intensities near the maximum of the solar cycle. He has observed red arcs to the north of Haute Provence. Considerable discussion of red arcs followed. On one occasion Roach observed an arc at the same time that Barbier was observing it, the arc extending at least from France across the U. S. plains. On some occasions Roach has observed the arcs in the magnetic zenith above Cactus Peak; he places both their height and width at several hundred kilometers. Although they do not appear to be auroral in nature, Rees pointed out that red arcs appear quite frequently over Alaska just prior to bright aurora.

T. M. Donahue (*France*) discussed sodium twilight airglow. The observations appeared rather variable over Haute Provence, France, and extremely variable over Tamanrasset, Sahara. An altitude of 85 km was found frequently for this airglow, and, at times, values more than twice as large were observed at Tamanrasset. There seemed to be a correlation between the thickness of the layer and its height, the layer appearing thin when it was low. Dr. Hunter stated that the sodium twilight glow was quite consistent over Saskatoon, but that more variability was observed at Fort Churchill.

Seventh Session: Geomagnetism and Aeronomy

E. H. Vestine (*USA*) discussed the effect of local particle-acceleration on auroral isochasms as defined by the integral invariant, which is given by the integral of the component of the trapped-particle velocity parallel to the magnetic field taken along the magnetic line of force between mirror points. Vestine pointed out that if a local acceleration process were active in the auroral region in such position as to increase the particle velocity paralled to the magnetic field, the arc length between mirror points must necessarily decrease. If the local acceleration mechanism does not change the magnetic moment of the particle, then the mirror points must move both downward toward the equator. By considering the paths of positive, negative, and trapped particles, it was pointed out that an electric field due to charge separation could be produced. This electric field is in the right sense to drive the observed polar electrojets. Vestine mentioned several important current problems in geomagnetism, including (1) an analytical description of the polar electrojet, (2) the relationship between geomagnetically trapped particles and the aurora (the Van Allen radiation belt contains too little energy to account for the aurora), (3) an explanation for the existence of a polar ionosphere during the long polar winter night, and (4) an explanation of the various space probe results, such as the current ring at ten Earth radii and the 2½ gamma interplanetary magnetic field perpendicular to the ecliptic plane as measured by Sonett and his coworkers.

In answer to (3), *F. S. Johnson* (*USA*) suggested that the existence and behavior of the polar ionosphere in winter darkness is due to its connection by geomagnetic field lines with the opposite polar ionosphere which is illuminated by sunlight.

J. A. Jacobs (*Canada*) reported that his previously deduced relationship between the period of micropulsations and the latitude is invalid.

R. A. Helliwell (*USA*) and his co-workers have determined the electron density in the equatorial plane to a distance of about 5 Earth radii. The analysis was made first by noting that the frequency of the 'nose' of the nose whistler defined the latitude of the propagation path because the nose frequency depends only on magnetic field strength. The electron density at the top of the path for each latitude was obtained from a plot of nose frequency versus time delay between the initiation of the spheric and the arrival of the nose whistler. The results of this anslysis showed that the electron number density is directly proportional to the geomagnetic field strength, that is $N \propto 1/r$. Another result of this analysis was the detection of an annual variation in the electron density curve; the electron density was found to be uniformly a factor of 2 higher in December than in June. No theoretical explanation was offered for either the $1/r^3$ density distribution or for the annual variation.

Eight Session: Formulation of Conclusions

At the last session held Friday afternoon, July 22, each chairman quickly summarized the highlights of his session. Very little additional discussion took place.

Conferees agreed unanimously that the conference had been very stimulating. Special thanks were expressed to M. Nicolet and J. O. Cardús for their work in arranging for the Symposium, and to the University of Copenhagen for providing the physical facilities.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

PHYSICAL OCEANOGRAPHY

General

The International Association of Physical Oceanography held meetings for the presentation of papers each day, July 26 to August 5, inclusive. Business meetings were held on July 26 and August 2. The Presidential address was presented on the morning of July 27 (see under Sessional Meetings.)

The first plenary session of the IAPO was concerned primarily with the reports of the scientific committees, the re-appointment or the appointment of new members to the committees, submission of national reports, a discussion of administrative matters and presentation of papers. The following Committees reported: Tides; Mean Sea Level; Oceanographic Observation from Weather Ships; Bibliographic Classification; Geophysical Year, Current Measurements; Bathymetric Charts and Chemical Oceanography. It was proposed that committees on Radiant Energy in the Sea, Marine Littorals, Nomenclature of Minor Bathymetric Features be organized. An *ad hoc* committee for each was appointed. The union requested IAPO to make recommendations concerning World Data Centers, and an *ad hoc* committee consisting of Deacon, Bohnecke, Hela, Carruthers, Smed, Lyman, and Kolesnikov was appointed.

J. N. Carruthers discussed a proposal from South and Central American countries to establish committees for an institute in Peru to study equatorial Geophysics. Members of the IAPO formally supported the suggestion.

National reports were received from Canada, United Kingdom, Germany, Japan, Russia, and India.

Dr. Kullenburg presented the secretary's and the financial reports.

A considerable amount of time was taken up with a discussion of what action the Association should take regarding World Data Centers. Some delegates favored a strongly worded resolution encouraging the continuation and expansion of the activities of the present World Data Centers. Others groups were equally convinced that private exchange of data bebetween individuals and institutions should be encouraged, and that the Association should not strongly endorse the World Data Centers. A compromise resolution commending the work of the World Data Center, and also encouraging individual exchanges of data was finally approved. A second resolution was passed recommending that all sea level data be directed to the long established Permanent Service on Sea Level, rather than to the World Data Centers.

Recommendations to promote a new general bathometric chart of the oceans were approved; these recommendations include a proposal to establish a permanent service on the general bathometric chart of the oceans.

With the completion of his second term as President of the International Association of Physical Oceanography, Dr. Haakon Mosby now retires, as required by the Statutes of the Association. The slate of Officers and Executive Committee Members for the next three years, was presented by the nominating committee, and the nominees were elected by acclamation. The list includes, also, five members who have held their positions during the last three years; in the following list of newly elected Officers and Executive Committee Members, those new to their positions have been indicated by an asterisk.

OFFICERS AND EXECUTIVE COMMITTEE

President: George E. R. Deacon* (Great Britain)

1st Vice President: V. G. Kort (USSR)
2nd Vice President: Ilmo Hela* (Finland)
Secretary: Börje Kullenberg (Sweden)
Deputy Secretary: M. M. Eyries (France)
Members, Executive Committee: Koji Hadaka (Japan), H. B. Hachey (Canada), G. O. Dietrich (Germany), John Lyman (USA).

Scientific Committees

The Committee on Bibliography, and the Committee on Tides were both continued under the Chairmanship of Andre Gougenheim.

Acting on a proposal submitted by Vsevolod P. Zeukovich (USSR), a new *Committee on Near Shore Oceanography* was appointed to gather information from individual scientists and existing organizations as to their present activities and views, to prepare a report in the light of the answers received, to issue a memorandum indicating the most desirable lines of future work, and to suggest the holding of a symposium from which the most desirable organization plan would emerge. An informal advisory group was appointed to assist the Executive Committee in making decisions relative to symposia and sessions in acoustics and seismic studies of the oceans; Arthur Maxwell (USA) was designated as chairman.

The IGY Committee of the Association was discontinued, as it was felt that its functions had been completed.

The Committee on Chemistry was reorganized in order to provide better liason with the SCOR Committee on Chemical Oceanography for the Indian Ocean program; Dr. Dayton Carritt (USA) was designated chairman of this reorganized committee.

A *Committee on Radiant Energy in the Sea* was appointed, having as a major purpose the standardization of terminology.

Members of the Scientific Committees are:

Tides: A. Gougenheim (France), Chairman; C. M. Cross (Canada), L. P. Disney (USA), W. Horne (Germany), C. L. Pekeris (Israel), J. R. Rossiter (Great Britain), L. N. Srettensky (USSR), V. V. Timonov (USSR).

Mean Sea Level and its Variations: R. W. Knox (Monaco), Chairman; J. R. Rossiter (Great Britain), Secretary; L. Cahierre (France), G. H. Chug (———), L. P. Disney (USA), E. Lisitzin (Finland), J. Pattullo (USA), P. J. Wemelsfelder (Netherlands), S. Yamaguti (Japan).

Oceanographical Observations from Weather Ships: D. C. Archibald (Canada), Chairman; O. H. Saelen (Norway), Secretary; A. Gougenheim (France), P. Groen (Netherlands), J. Lyman (USA), R. B. Montgomery (USA), K. Terada (Japan), H. Thomsen (Denmark), R. S. Glover (Scotland).

Bibliographical Classification: F. Model (Germany), Chairman; R. Dorrestein (Netherlands), N. Loktionev (USSR), H. McCall (———).

Editorial Committee on Current Measurements: H. Weidemann (Germany), Editor; S. von Arx (USA), H. Charnock (Italy), N. N. Sisoev (USSR), Y. Takenouti (Japan).

General Bathymetric Chart of the Oceans: G. Böhnecke (Germany), Chairman; R. Fraser (The Netherlands), Secretary; N. Atherton (Great Britain), B. L. Bezrukov (USSR), B. Heezen (USA), H. F. P. Herdman (Great Britain), R. W. Knox (Monaco), H. W. Menard (USA), C. Gaibar-Puertas (Spain).

Chemical Oceanography: D. E. Carritt (USA), Chairman; A. F. Richards (USA), Secretary; S. W. Brujewicz (USSR), L. H. N. Cooper (Great Britain), B. Ketchum (USA), Y. Miyake (Japan), J. N. Nanda (India), M. Picotti (Italy), H. Postma (The Netherlands), B. A. Skopinzey (USSR), J. H. D. Strickland (British Columbia), K. Sugawara (Japan).

Bibliography of Physical Oceanography: A. Gougenheim (France), Chairman; F. Model (Germany), Secretary; G. Aliverti (Italy), J. N. Carruthers (Great Britain), A. Ph. Laktionov (USSR), A. R. Miller (USA), J. Smed (Denmark).

Radiation in the Sea: N. Jerlov (Sweden), Chairman; J. Tyler (USA), Secretary; A. Ivanoff (France), J. Joseph (Germany), A. F. Kolesnikov (USSR), T. Sasaki (Japan).

Near Shore Oceanography: V. P. Zenkovitch (USSR), Chairman; H. J. Schoemaker (The Netherlands), Secretary; R. Bonnefille (France), J. M. Caldwell (USA), N. Campbell (Canada), J. Joseph (Germany), C. A. M. King (Great Britain), O. Kolp (Germany), E. LaFond (USA), O. L. Leontiov (USSR), D. W. Pritchard (USA), M. Uda (Japan).

Sessional Meetings

Formal papers were given at eight sessions. The range of subjects was broad, but particular

emphasis was given to the subjects of ocean currents, marine geology, and waves and tides.

(July 26)

Following the business session, *W. H. Munk* (USA) presented a paper by Munk, Snodgrass, and Miller on *'Directional Recording of Ocean Swell from the South Pacific.'* He reported that they had obtained a directional spectrum in the low frequency position of the ocean wave spectrum, and that the signals from individual storms in the South Pacific may be identified. Results indicate that a two-week forecast of swell from that area is possible. Two sets, believed to have originated from a storm south of Madagascar, were followed along a great circle route. Certain aspects of the data require further analysis.

W. S. Wooster (USA) followed with a paper on *'The Peru Current, an Eastern Boundary System.'* The characteristic features of eastern boundary currents were summarized as common surface and sub-surface features, including equator-ward flow along the continental boundaries, a comparatively low salinity in the surface waters, a high, near-surface, concentration of nutrients associated with upwelling and the near-shore sub-surface counter current. The seasonal variations in the oceanographic features (Peru current) are related to the seasonal variations in mean wind stress and the consequent Ekman transport perpendicular to the coast.

Papers by *B. Saint-Guily*, *G. Wust*, and *B. Bogorov*, were read by title.

A paper by *A. A. Zverev* (USSR) (presented by B. A. Nelepo) analyzed the physical oceanography of the Davis Sea area in the Antarctica; it was based primarily on Russian data.

G. L. Pickard (USA) gave a well-rounded paper on fjord-type estuaries. *R. Frasseto* (USA) *R. H. Backus*, and *E. Hays* reported on studies of the relation between sound-scattering layers and thermal structure, as measured with a continuously recording thermister. Of particular interest was the observation that in the Straits of Gibraltar the scattering layer rises to the surface at, or near, sunrise, and becomes globular during the day; this is unlike the vertical migration of such layers in the open sea.

H. Lacombe (France) reported on direct current observations made in the Straits of Gilbraltar.

(July 27; A.M.)

President Hakon Mosby gave his Presidential Address on 'The Continuity of the Ocean'. A model was developed for consideration of the vertical velocity and the advective renewal in the deep waters of the ocean. Empirical data, when used with the model, yielded, for example, that the vertical velocity in the deep waters of the Mindanao Trench was 5m per year; 25m per year in the Norwegian Sea with an advective renewal of about 15 per cent per year. Near 10° north latitude in the Atlantic, at a depth of 1700m, the vertical velocity was calculated to be approximately 60m a year, with a weak (6cm per second) transport to the south.

P. Welander (Sweden), gave a paper relating to the vertical heat transport in the deep sea. He estimated the roles of advection and diffusion from hydrographic data. His computations suggested that heat transport mechanisms in the deep sea are primarily the result of advection. Considerable discussion followed.

L. H. N. Cooper (Great Britain) discussed the results from a station in the Bay of Biscay, in the light of the conclusions in the Presidential Address and the Welander paper. In the greater depths at the Station, vertical variations, particularly in content of oxygen, suggest a comparatively short term for vertical oscillations in the deep waters, with periods as short as a few days.

Three of the five papers scheduled for this session were read by title.

CURRENTS

(July 28)

This constitutes a group of more or less unrelated papers, of which the following were particularly noteworthy.

H. L. Grant (Canada) discussed the studies of turbulent movements, being made in Canada, describing the work by means of a platinum film.

J. A. Knaus (USA) described recent direct measurements of the Pacific-Equatorial counter current, in which the existence of large changes in the zonal intermediate transport was demonstrated. He reported also on his measurements in the North Pacific, with shallow floats, of internal waves and rotating circulation with speeds of 5 to 12 cm/sec at depths of several thousand meters. This appears to be an inertial phenome-

non related to the latitude at which the measurements were made.

F. Ostapoff (USA) discussed the geostrophic mass transport through the Drake passage, and by the choice of reference level apparently revealed significant westward transport at depth through the passage. Deacon and others questioned the applicability of the geostrophic assumptions on this region and indicated that observations were not consistent with the apparent westward flow.

(July 29)

M. Bossolasco and I. Dagnino (Italy); Some Properties of the Coast Currents in the Ligurian Sea.

Current measurements have been carried out in the Ligurian Sea by following floating boxes on lights with the aid of land based theodolites. The currents were correlated with meteorological factors.

J. N. Carruthers (Gt. Britain); Some new Instrumentation Deemed Essential, and Progress in Providing and Using It.

Carruthers is continuing with the construction of simple current meters along the line he has followed for the past 10 years. He develops his instrument according to the following principles: (1) they should be constructed in such a way that untrained people in technical aspects should also be able to use them; (2) they should be used in all sea states, being insensitive to pitch, roll, and vertical movements.

Basically there are good ideas, but the technical development is not always up-to-date. The recording device, stiffening of a jelly by cooling, is not so simple as required, and does not give a good indication because of internal seiches on the water-jelly interface.

W. Krauss (German); The Current System of The Internal Seiches of the Baltic.

Two seiche systems have been studied, i.e., in the Gulf of Botnia and in the western Baltic. In the first, a period of 39.0 hours was found. In the latter, 3 seiches of 27.5, 17.6 and 11.5 hours were found. The internal seiche is closely related to the 30 m. temperature.

By mathematical development of the hydrodynamical equations, the water velocity connected with the seiches is derived in two dimensions. The results of the hydrographic cross section give amplitudes of 3 to 4 meters. The greatest period and amplitude is in the region of greatest depth. The current field shows that the easterly flow is associated with seiches (surface waters). The deep current has not yet been calculated; it is assumed to be a compensatory return flow.

V. Romanovsky (France); L'hydrologie des detroits du Bassin Occidental de la Mediterranee.

Current measurements in the region of Bonifacio in the Tyrrhenienne Sea show that the current is directed toward the west and arrives there from the north. The current has a velocity of 53 cm/sec at the period of observation and the tide was of the order of 30 cm.

The high salinity values in pockets is surprising. On the assumption that these water pockets may originate in the Straits of Messina, a study of the literature was carried out. It was found on three occasions that high saline waters were found in the Strait near Reggio.

(Reporter's comment; the Strait of Messina is a known region of submarine breakers, which may cause high salinity water pockets to be lifted to the surface).

V. Romanovsky (France); Les mouvements longitudinaux et verticaux des eaux littorales Mediterraneennes.

The current system near shore between the Italian border and Cape Sicie has been studied intensely. It was found that the permanent current is running from the northeast to the southwest; the velocity varies between a half and one knot with an average of 0.7 knots. This current system is influenced by three types of wind systems: (1) east winds, connected with a meteorological deep in the Gulf of Genoa; (2) the mistral—a strong northwest or west wind; (3) a calm weather situation with alternating sea and land winds. Nos. (1) and (3) influence the permanent current but little. The mistral, on the other hand, has a strong influence extending far out at sea. Measurements of the hydrographical structure carried out in the Gulf of Nice before and after a mistral demonstrate radical changes in the current system down to 500 m.

Odd H. Saelen (Norway); Studies in the Norwegian Atlantic Current.

A hydrographic section across the current—taken first by H. Hansen in 1927—was repeated several times during the years 1947-59. This section shows after repetition a high variation in the computed volumes transported. In 2 to 3 days the transport increased from 2.1×10^6 m³/sec to 3.8×10^6 m³/sec. Either the variations are actually as high as calculated, or an experimental error is made. One possible source of error was studied. It was supposed that the current velocity varies in the 1000 m. reference level, as bottom measurements carried out during 1956 seemed to indicate that to be the case. However, repeated studies during 1959 disproved this theory. The direction of bottom current and the velocities were variable. On one occasion the bottom current was stronger than the surface current. No tidal periodicity could be found.

A new station system on a two dimensional pattern was evolved. Vortices became more apparent. The eddies seem to be semipermanent, and are not caused by the unsynoptic condition.

Waves and Tides

This session was quite worthwhile in spite of the fact that a number of promising papers announced for the session in the printed schedule were not presented because of the absence of the authors. Included in this group were four papers by investigators from the USSR. However, abstracts of these papers were made available to the delegates. Substitute papers were given by *V. Romanovsky* and A. G. *Kelesnikoff*.

Perhaps the most impressive paper of the entire session was that of *C. L. Pekeris*, and *M. Dishon* (Israel) on the theory of ocean tides. This was enhanced in large measure by the dramatic delivery of the senior author, who described a numerical analysis of the tides in the world-wide oceans for the M_2 and K_1 constituents. In spite of the rather coarse grid of 15° interval, the numerical calculations using the tide potential as input lead to a rather remarkable agreement between the computed amphidromic regions and those deduced from empirical data by Dodson and others. However, in spite of the impressive nature of the results, it is difficult to see how the important influence of the continental shelf regions can possibly be accounted for in a system that employs a grid scheme which surely leaves the latter regions completely unresolved, in spite of the allowance for variable depth. A further drawback of the computing system is the necessity of carrying out a 'brute force' matrix inversion of fantastic proportions.

Another outstanding paper was that of *C. S. Cox* (USA) on recent measurements of internal waves in the Pacific. A rather unique system of measurement of temperature for multiple levels at a fixed point in deep water (1000 meters) was described. The preliminary results of these measurements emphasize the need for measurements at multiple levels in order to describe the spectrum of internal waves in an unambiguous manner.

Marine Geology

Nine papers on Marine Geology were scheduled, but only five were given. One of these was a paper by *A. G. Richards*, U. S. Navy Hydrographic Office, in which he described a plastic coring tube—developed in that office—for collecting cores of sediments for making soil mechanics studies. In discussion, Richards indicated that he has found no correlation between water content and shear strength in fine sediments, a finding that is apparently contrary to experiences of others.

Symposia

Symposium: Overflow of North Atlantic Submarine Ridges by Cold, Deep, Sub-Arctic Waters

This symposium consisted primarily of descriptive papers in which the work of recent cruises to the area was discussed. Results from British, Danish, and German operations were included. The approach has been essentially classical, although some modern current measurements were also reported. To an American oceanographer, it was surprising to listen to an extended discussion of a situation where sub-Arctic water is believed to flow over a ridge and to spread along the bottom, but where the method of isotropic analysis and consideration of the densities of the waters involved have apparently not played an important part in the investigation. *K. G. Bowden* (Gt. Britain) in the sole theoretical paper of the symposium, de-

veloped the equations that are applicable to the problem. In a concluding paper, *J. B. Tait* (Gt. Britain) discussed preliminary results of the ICES Iceland-Furve Ridge expedition, a nine-ship synoptic survey that should permit the maximum utilization of the descriptive approach.

Symposium: Tidal Estuaries
(See also under Scientific Hydrology, July 28)

The majority of the papers presented in this afternoon session were either of a review or of a routine character. An exception to this was an excellent presentation by *K. J. Bowden*, (Gt. Britain) who reported on a series of current and salinity measurements in the Mersey Esturary. This estuary has long been considered to be vertically homogeneous, without the characteristic circulation pattern of a partly mixed estuary. Dr. Bowden showed, however, that even the slight vertical salinity difference of 1 per cent between surface and bottom, in this estuary, results in a net circulation pattern with seaward flow in the upper half of the water column, and opposite flow in the lower layers. Computations were also made of the vertical variation in eddy stress and non-advective turbulent salt flux.

D. R. F. Harleman (USA) presented a paper on *Turbulent Diffusion in an Idealized Estuary*. He reported on observations made in a laboratory flume, in which controlled and measurable turbulent energy could be introduced. He showed that the characteristic two-layered convective flux could be expressed in terms of an 'apparent' horizontal diffusion coefficient, the value of which is predictable from certain energy dissipation parameters and a measure of the vertical stratification.

D. W. Pritchard and *J. H. Carpenter* (USA) presented techniques employed in artificial tagging of a water volume, using the tracer Rhodamine-B, for measuring circulation patterns and diffusion in natural water bodies. Preliminary results of several experiments using this tracer in the study of horizontal diffusion were presented.

Symposium: Topography, Morphology, and Geology of the Ocean Floor
(July 29, With IAG, and IAS)

A large portion of the morning session was devoted to the question of the 'rift' valley along oceanic ridges, as proposed by Heezen, who has described these ridge-and-rift features on a world-wide basis, and has suggested the possibility that the oceanic crust has grown, as a substitute for the more common idea of a growing or shifting continental crust.

The details on marine topography still appear so vague that many papers on the same geological area gave different interpretations. Stock, using hydrographic data on bottom water, and available data on topography, showed a bottom chart of the Indian Ocean that is significantly different from a chart of the same area presented by Fray of Lamont Geological Observatory. Also, German oceanographers presented a very extensive and detailed survey of the area south of Iceland, which showed no evidence of the rift valley on that portion of the Mid-Atlantic ridge.

A high spot of the morning session was a paper given by *Charles Cox* (USA) on electromagnetic currents flowing along edges of the ocean. This theoretical study, based in part on empirical evidence, demonstrated how geophysical investigations can contribute greatly to our understanding of physical processes in the ocean.

The afternoon session was essentially a seminar of the Lamont Geological Observatory. Most of the papers described the seismic, gravity, magnetic, and topographic measurements made on the VEMA in different parts of the World. The scope and quality of the work of the Laboratory was impressively illustrated. Of particular interest was Talwani's interpretation of the gravity anomalies measured across the mid-Atlantic ridge; he gave three interpretations that may be equally applicable to other areas in the World which exhibit similar geophysical properties.

In addition to the Lamont papers, there was a small group of papers concerned with the structure of layers in the bottom sediments. *Hersey* presented echograms that showed clearly layering in the upper few meters of the sediment, and demonstrated how their origin might be interpreted by having a continuous record of the layers across an entire basin.

Symposium: Mean Sea Level
(See also under Geodesy, July 30)

Problems concerning mean sea level concern both Oceanography and Geodesy, and it is

encouraging that the two Associations held a joint session on this subject. In the past, both oceanographers and geodesists have not been sufficiently aware of each other's pertinent work.

I. Hela, (Finland) a leading investigator in this field, gave a summary of the causes leading to variations in sea level. In particular, he referred to the effects of atmospheric pressure, of piling up by winds, and of the dynamics of circulation. He suggests that 19 years is the basic interval for computing long-term trends. He gave a summary of 21 desirable corrections to apply to the actual time-variable sea level, in order to obtain a geodetically applicable measure of sea level. In the discussion that followed, Disney pointed out that in one location in Alaska the rise of the land area exceeds 3 cm per year.

R. W. Fairbridge (USA) discussed some of the geological aspects of sea level. He showed slides illustrating wave action in the process of cutting terraces, for which he used Dutch records of sea level as far back as 1700, temperatures at Berlin, and Willett's sunspot indexes. Fairbridge discussed the relation between these time series.

J. R. Rossiter (Gt. Britain) discussed his paper on *The Secular Variation in Sea Level and the Nodal Tide (18.6 year period)*. This long tide does not necessarily obey the equilibrium argument, because of a possible non-linear interaction with tides of shorter period, particularly in shallow seas.

J. Patullo (USA) discussed the seasonal variation in sea level in the light of the IGY measurements. The correlation with steric variations (related largely to temperature) is excellent at middle and low latitudes.

W. H. Munk (USA) plotted the power spectrum of sea level between 0.01 and six cycles per year (cpy) based on the oldest tide records. Apart from the seasonal line spectrum, and a weak peak at 0.85 cyp, due to the Chandler wobble, the spectrum is smooth and shows no significant periodicities. Between 0.1 and one cyp the energy density is at 10 cm^2/cpy, and it rises to 10^3 cm^2/cpy at 0.01 cpy. There is some evidence that meteorological effects predominate above 0.1 cpy, continental up and down movements between 0.01 and 0.1 cpy, and secular variation below 0.01 cyp.

R. Reid (USA) discussed the effect on sea level of systematic differences between the density of Atlantic and Pacific waters. The difference in dynamic height (with respect to 4 km) between the oceans is of the order of 68 cm, and should be of considerable geodetic consequence.

D. Cartright (Great Britain) discussed a method for joining the leveling networks of France and England (see *Bul. Geod.*, May 1960). This consists essentially of computing dynamic sections across the channel, allowing for wind stress and various tidal effects. The most important contribution to cross-channel slope is due to the Coriolis Force or the mean flow, and this study can be aided by measuring the electric potential difference across the channel as a measure of water transport. Records of tide gauges, established especially, provide the control necessary in these calculations. The expected precision is of the order of one cm.

Symposium: Tsunamis and Storm Surges

(August 1)

Of practical interest in the first session was the description of the seismic sea wave warning system by *E. Roberts* and the description of the tsunamis originating from the recent earthquake in Chile. The papers by *K. Wadati* and *R. Takahasi* (Japan) in regard to storm surges and tsunamis were quite evidently of considerable merit but the authors attempted to cover far too great a scope of subject in an already overscheduled session.

(August 2)

The remainder of papers not given in the first session were presented on the afternoon of August 2. The firm guidance of Chairman Proudman made this a record session in efficiency and resulted in valuable discussions following each paper. The most noteworthy of this group of papers was clearly that of *J. R. Rossiter* (Gt. Britain) who departed from his announced paper to give the results of some very interesting theoretical studies of the coupling of surges and tides in shallow estuaries. As anticipated, *W. Munk* (USA) presented a very lucid description of the results emerging from his continued studies of the spectra of long waves observed along Pacific shores. A somewhat debatable point emphasized by Munk is that the local topographic characteristics near the

recording station determine the nature of a tsunami record, and that one must takes care in interpreting the nature of the associated disturbances in deep water, or at source, from records at coastal stations.

Several papers were essentially attempts to relate fluctuations of water level to generalized models, or to specific sea floor topography; in some cases, high speed computer methods were used to solve equations of motion, or approximations.

(August 3)

J. P. Rothi (France) reported on a resolution to establish an international tsunami warning service.

E. B. Roberts (USA) reviewed the work of the United States Coast and Geodetic Survey warning system in the Pacific. Since its inception all major tsunamis have been successfully predicted. He expressed the willingness of the United States to discuss with any other country the extension of the present system.

L. M. Murphy (USA) reported on the details of operations of the warning system during the great Chilean earthquake. The prediction of arrival time was accurate to about *one minute*.

C. Lommitz (Chile) discussed the Chilean earthquake. The first water motion on the coastal side was definitely upward. He showed some excellent local tide records, and a series of photographs of the damage done.

E. F. Savarensky (USSR) discussed tsunamis studies in the USSR. The work was started following the Kamchatka earthquake of 1952. Local epicenters are determined from a close network of seismic stations. Theoretical studies of the effects of bottom topography are being carried on.

A. Galanopolous (Greece) has studied the records of Greek tsunamis that have occurred since the time of antiquity. He relates the disappearance of Atlantis to a tsunami. The evidence favors landslides as the cause of tsunami generation.

K. Wadati (Japan) reviewed recent studies in Japan, where storm surges are a serious problem, and where they are widespread and frequent. A method of forecasting surges and tsunamis is now operative in Japan. The forecasting of surges is based on a numerical solution of the dynamic equations, allowing for both pressure and stress. *I. Takahasi* continued the review of the Japanese work.

J. R. Rossiter (Gt. Britain) reviewed practical aspects of storm surges. Methods for prediction are still in the stages of experimentation. Rossiter differentiated between the effect of slowly moving cyclones, which depends on wind stress and can be handled by quasi-static methods, and that of fast-moving hurricanes, which requires dynamic considerations. Predictions for the North Sea area have been astonishingly good. Rossiter reviewed the non-linear interaction between tides and surges.

G. W. Lemmon (Great Britain) is concerned with storm surges on the west coast of England. A prediction based on steady-state correlations with off-shore geostrophic winds led to quite satisfactory results except for short-lived disturbance. The dynamic problem was attacked by representing the stress as a series of heaviside functions. Experience with seven severe storms has led to the formulation of certain empirical rules for prediction of surges. Prediction to within 1 foot, and ½ hour in time, is feasible.

C. Bretschneider (USA) discussed certain engineering aspects of storm surges in Chesapeake Bay and elsewhere.

W. H. Munk (USA) discussed power spectra of low-frequency, background and tsunami waves, and found that these are remarkably reproducable.

R. Reid (USA) has applied the method of characteristics to the propagation of a surge and/or tide through a variable channel, assuming subcritical flow. He discussed the numerical stability of the computing method.

Symposium: Circulation of Carbon Dioxide in the Atmospheric and the Ocean

(Co-sponsored by International Association of Meteorology, August 3–4)

A joint symposium with the Association of Meteorology on the circulation of CO_2 in the atmosphere and ocean was held on 3rd and 4th of August, Kurt Buch opened it with a historical review.

C. D. Keelings (USA) then reported on the results of the IGY atmospheric-CO_2 measuring program in the Pacific, giving some newer material than in the May 1960 issue of *Tellus*. All of his time series show a secular increase of the order of 1.2 ppm yr^{-1}, and most of the sta-

tions have an annual cycle with double amplitude of 6 ppm, the South Pole being an exception in having no annual cycle.

Erik Eriksson and *B. Bolin* (Sweden), discussed the kinetics of CO_2 exchange between sea and atmosphere. Bolin states that bubbles in the sea are not significant in this process.

K. Ya. Kondratiev (USSR) reported results of calculating the influence of CO_2 changes on atmospheric temperature, concluding that the 10 per cent increase in the last half century has raised the temperature 0.05°C.

Taro Takatashi (USA) found the ppm of atmospheric CO_2 over the Atlantic to be greater than in the surface sea water, except between the Equator and 30°S. He found 316.3 ppm as the mean from latitude 60°N to latitude 60°S lost, and estimated total atmospheric CO_2 at 2.46×10^{18} g.

N. W. Rakestraw (USA) enlarged on the downwind sea and atmospheric CO_2 results, which likewise show air below water except between latitude 20°S and 35°S in the eastern Pacific.

D. W. Hood (USA) reported some anomalous results from American Mediterranean, where observed pCO_2 values in surface waters differed greatly from those calculated from the constants of the buffer system.

Wallace Broecker (USA) described some measurements of mixing rates, derived from C^{14} determinations in the sea and in lakes, which yield 7 years as the mean residence time of CO_2 in the atmosphere.

K. O. Münnich (Germany) found that since 1958 there has been an annual cycle of CO^{14} in the atmosphere, with the northern hemisphere maximum in July and the minimum in January-March. The curve for Pretoria is apparently displaced six months, like the northern hemisphere Sr^{90} curve. He likewise finds gas bubbles to be of little effect in equilibrating between sea and atmosphere.

John Lyman (USA) presented some calculations of total CO_2 as a function of pCO_2 in the sea, with and without saturation with $CaCO_3$, which agreed rather well with similar results of Bolin and Eriksson, given in the Rossby Memorial Volume.

John Kanwisher (USA) discussed further the mechanism of gas exchange at the sea surface. He pointed out the importance of ocean waves and the associated form in this problem, and presented meteorological calculations to show that the southern hemisphere is the chief area of exchange, being 20 per cent more effective than the northern hemisphere in December, and 300 per cent more effective in July.

Yasuo Miyake (Japan) described measurements of the transfer of CO_2 from air to water, using C^{14} as a tracer.

Aarno Voipio (Finland) closed the session with a review of the kinetics of the system $CO_2 + H_2O$ in sea water.

Symposium: Radiant Energy in the Sea

(Co-sponsored by International Association of Volcanology, August 4)

(1) *Effects of biological products.*

K. Wirtki described a turbidity layer in the Coral Sea that was not related to temperature or density structure, but showed some similarity to the distribution of phytoplankton and total particles. Point by point the correlation was not close, but the general distribution was similar. At many stations there was one percent light near the 80 to 100 meter depth.

K. Kalle (Germany) gave further information about 'gelbstoff', indicating that carbohydrate-humic acids (Melanoidines), are important contributors to this color in the seas, and that these may be derived from decomposing plankton.

F. A. J. Armstrong and *G. T. Boalch* (Gt. Britain) discussed UV absorption, and particularly the fact that this indicates biological origin. This absorption undergoes seasonal variation, with a maximum in spring or summer, which seems to correlate with the decay rather than with the growth periods of plankton.

(2) *Reflection from the surface*

Z. Sekera (USA) gave a detailed exposition of reflection, and of the effects of a flat sea surface on the Brewster, Babinet and Arago points, but his argument that these effects must be considered in studies of submarine illumination was unconvincing.

G. Neumann (USA) spoke on *'The Albedo of the Sea Surface;'* this gave a clear evaluation of reflection from the surface as a function of sun altitude and cloud cover. He demonstrated that reflection from below the surface could

account for 50% of total reflection, which lent support to the idea that these should be considered as one process.

(3) *The biological production of light.*

G. L. Clarke (USA) presented a paper on *Light in the Sea, with Special Reference to Bioluminescence.* Particularly interesting was his discussion of the distance a flashing organism could be 'seen' in the sea. Theoretically this might be as much as 170 meters, but under less than ideal conditions could be much less. Clarke has successfully measured the attenuation of light to depths as great as 950 meters; at greater depths in daytime at shallower depths at night, bioluminescence is more intense than the attenuated surface light. Some luminous flashes are 10^4 greater than background, so that for life in the sea, this source of light overshadows the attenuated daylight or moonlight at some depth.

(4) *Responses of organisms to light.*

Talbot Waterman (USA) discussed the structure and physiology of photoreceptors. He showed evidence that many arthropods can respond directly to polarized light, though the response can be intensified or modified by changing the luminous distribution by suspended particles or patterns external to the laboratory jars used for the test. It was clear that we do not know how sensitive invertebrate eyes are to light, and until this is studied further, ideas about deep scattering layer responses must be speculative.

R. I. Currie (Gt. Britain) emphasized that a phytoplankton cell in the water will receive light from all directions, and that we should measure light in an appropriate way for photosynthesis experiments. For this purpose he has designed and used a spherical scalar photometer that integrates total energy over the period it is exposed. No comparisons with the usual type photometer were given, but Tyler computed a 20% difference, which would recommend Currie's method.

E. M. Kampa (USA) described the penetration of light in the Sargasso Sea, in the San Diego Trough, and in the Mediterranean. The light was measured by narrow band interference filters and complete spectra were obtained at each of the locations.

D. P. Boden (USA) described the penetration of light of various wave lengths both at midday and at twilight. The spectral composition of the light changes as a result of the transparency of the water, and there is also a twilight shift to shorter wave lengths.

Symposium: Comparative Chemical Oceanography
(August 5)

A report by *R. Greenhalgh* (Gt. Britain) and *J. P. Riley* (Gt. Britain) indicates that the concentrations of perchlorate ion in sea water (northern hemisphere) is less than 0.04/ug/ml. These results are significant because previous results have suggested that perchlorate, formed from chloride, could be as high as 150 ppm a concentration high enough to disturb the conservative properties of chlorinity.

R. A. Cox (Gt. Britain) described their program designed to re-evaluate the chlorinity-conductivity-density relationships. Preliminary results indicate that the presently accepted relationships by Thomas, Thoreprau, and Utterback are in error by as much as 0.06 per cent S at high temperatures and salinities. Discussion disclosed both similarities and differences between the United Kingdom program and a similar study being conducted in the United States.

T. J. Chow and *E. D. Goldberg* (USA) reported on the distribution of barium at four Pacific stations. After correcting the solubility of $BaSO_4$ for temperature and pressure, they suggest that the sea is nearly saturated in deep water. The vertical distribution resembles that of Ra and they suggest bio-transport as impartial in establishing the distribution.

L. H. N. Cooper (Great Britain) described the use of silicate distributions in tracing water movement, illustrated by the movement of Norwegian sea water along the east coast of the United States, and by continuity in silicate distribution through the Pacific Ocean and into the Indian Ocean.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

VOLCANOLOGY
(including Geochemistry and Petrology)

General Report

The International Association of Volcanology held Section meetings and Symposia each day of the Assembly.

The Presidential address was delivered on the afternoon of July 26. Following the address, the Secretary's report was presented.

On Wednesday, July 27, the following appointments to Committees were announced: *Publications*: V. I. Vlodavetz (Russia), Chairman; P. Evrard (Belgium) N. Fisher (Australia) L. Glangeaud (France) G. Imbo (Italy) H. Kuno (Japan) M. Newman van Padang (Netherlands) A. Richards (United States).
Symposia: H. Kuno (Japan), Chairman; B. Gézé (France) M. Newman van Padang (The Netherlands), A. Rittman (Switzerland) H. Tazieff (Belgium) *Preparation of new Constitution and By Laws*: N. Fisher (Australia), (Chairman; Chris Oftedahl (Norway) J. F. Schairer (United States).

At the business meeting on August 4, the the following actions were taken:

(1) The following new officers, proposed by the nominating committee, for the triennium were unanimously elected:

President: A. Rittman (Switzerland)
Vice-President: G. A. Macdonald, Univ. of Hawaii (USA)
Vice-President: V. I. Vlodavetz (Russia)
Secretary: F. Penta (Italy)
Chairmen of Sections:
Section I (Active Volcanoes) M. Neuman van Padang (Netherlands)
Section II (Physics of Volcanoes) G. S. Gorshkov (Russia)
Section III (Physical Chemistry of Magmas) H. Kuno (Japan)
Section IV (Paleovolcanology and Plutons) B. Gézé (France)

(2) It was voted unanimously to establish a place for the prompt reporting of volcanic eruptions. Such reports should be sent to Prof. H. Kuno, Tokyo University; they will appear four times each year in the Bulletins of the Volcanological Society of Japan, and will also be sent to each National Committee for Volcanology, and other interested persons.

(3) It was voted unanimously to recommend to the IUGG that two symposia under auspices of IAV be held as follows:

(a) Symposium at Catania (Sicily) in October 1961, for about ten days, to discuss 'Formation of ignimbrites, hyaloclastites and related deposits.' Convenor—Prof. A. Rittman, Volcanological Institute, University of Catania, Catania, Sicily (excursions to pertinent areas will be arranged).

(b) Symposium in Japan (late May and early June 1962) on 'Prediction of time and place of volcanic eruptions and the relations between magmas and the nature of volcanic eruption.' Convenor—Prof. H. Kuno, Tokyo University, Tokyo, Japan. Excursion before, between, and after sessions.

(4) The new Statutes and By Laws prepared by the Committee were presented and adopted with but a single change. The French text, rather than the English, is to be authoritative text for their interpretation. The Statutes and

By Laws will be submitted to the IUGG for verification and confirmation.

About 150 papers were given during the sessions, under the four sections. A brief resume of the highlights of these sessions is given below. In addition to sectional papers, six symposia were given, four of which were under joint sponsorship with other Associations; the symposia were:

Geochemistry (with IAS)
Rock Age Determinations (with IAS)
Island Arcs (with IAG, IAS)
Ocean floor (with IAG, IAS, IAPO)
Study of Volcanic Gases and Sublimates
Relations between Volcanoes and Plutons

On Monday, July 25, a meeting of all geochemists was called, by P. H. Abelson, to follow the Symposium on Geochemistry, for the purpose of discussing the formation of a geochemical group, separate from the IAV. Opinion was unanimous that such a group should be formed for the specific field of Geochemistry. The matter was discussed further at a meeting on the following day. The group agreed unanimously to ask President J. T. Wilson to appoint an *ad hoc* Committee on Geochemistry, to serve until the close of the next General Assembly of IUGG. This Committee is to arrange programs for the next General Assembly, and to explore with geologists at the International Geological Congress and with the Commission of Geochemistry of IUPAC, both meeting at Copenhagen, August 15–25, as to the best way to provide for an organization of geochemists on an international basis. The *ad hoc* Committee on Geochemistry met later and elected the following officers:

President: L. T. Aldrich (USA)
Vice-President: A. P. Vinogradov (Russia)
Secretary: E. Picciotto (Italy)
Secretary: A. T. Tugarinov (Russia)

Other members of the Committee included C. W. Correns, Germany; S. Epstein, USA; B. Gézé, France; F. G. Houtermans, Switzerland; K. Sugawara, Japan; L. R. Wager, England; J. T. Wilson, Canada.

Sessional Meetings

General Geochemistry

On Thursday, July 28, a program of papers on general geochemistry was presented. Thirteen papers were given, relating to germanium content of tectites; meteorites; isotopes in volcanic rocks; dating methods; radiocarbon dates in sediments; and others.

Section I—Active Volcanoes

An all day session was held on Wednesday, July 27, 1960. There were discussions of welded tuffs, breccia-pipes (diamond bearing), volcano acoustics at active volcanoes, properties and mechanism of formation of volcanic glasses, et al. A paper by *Adrian Richards* (USA) caused considerable discussion of volcanic acoustics, and his quantitative approach to the evaluation of volcanic 'noise' in terms of intensity and wave length was commended; he was encouraged to pursue these valuable studies.

Section II—Physics of Volcanoes

A half-day session was held Friday, July 29, 1960. The major contribution at this session was given by *H. Tazieff* (Belgium) who had just returned from Chile. He gave an accurate account of the recent severe seismic activity there. Only one very minor volcanic eruption occurred. Major damage was done by the sinking of a narrow strip along the coast, by the ocean wave that followed the major earthquakes, and by the numerous and severe landslides caused by the quakes. Tazieff had a set of outstanding kodachrome slides to present graphically the story of the widespread destruction of life and property.

Section III—Physical Chemistry of Magmas

A half-day session was held on Tuesday, August 2, 1960, at which five scientific papers were given. A paper by *J. F. Schairer* (USA) on phase equilibrium studies bearing on the crystallization processes in basaltic magmas was of outstanding interest; it provoked more than an hour of interesting discussion, which emphasized the value and importance of laboratory studies in laying a sound basis for interpretation of rock and mineral origins.

Section IV—Paleovolcanology and Plutonism

A half-day session was held on Thursday afternoon, August 4, 1960. There were many papers at this session nearly all in French, with much discussion in French.

Symposia

Symposium: General Geochemistry
(July 25, 1960)

The symposium on Geochemistry was held in two sessions on Monday, July 25, and in co-sponsorship with the International Association of Seismology and Physics of the Earth's Interior (IAS).

The following papers were presented:

S. Epstein (USA): "Oxygen Isotopes in Rocks"

The variation in the ratio O^{18}/O^{16} in nature is known to be as great as ten per cent. The smallest value is observed for ice from the South Pole and the largest is for atmospheric carbon dioxide. The former is 6 per cent smaller than that in mean sea water; the latter is 4 per cent greater. Present measuring techniques are capable of detecting differences in this ratio of 0.01 per cent. Studies of constituent rock minerals such as quartz, calcite, magnetite and water, suggest oxygen isotope fractionation under equilibrium or near-equilibrium conditions. The extent of the fractionation decreases regularly with the estimated temperature of formation of the rock. For example the list: peridotites and dunites, gabbros and basalts, tonalites, granites and granidiorites, and granite pegmatites, is in order of increasing O^{18}/O^{16} ratio. The ratios in all of these minerals are much smaller than in cherts, shales, etc., and their values suggest exchange with a large reservoir of oxygen, possibly water.

Sufficient is now known about such isotopic equilibria to permit temperature determination.

J. Geiss, B. Hirt, W. Herr, E. Merz, W. Hoffmeister, J. Langhoff and F. G. Houtermans: Variations of Isotopic Abundance in Common Osmium of Meteoritic and Terrestrial Origin.

Rhenium–187 decays to osmium–187 with a half life of $(6.2 \pm 0.9) \times 10^{10}$ years as determined from the osmium content of dated rhenium minerals. If it is assumed that all terrestrial and meteoritic osmium has grown from primeval osmium of common isotopic composition existing at time $t = t_0$, then osmium existing in a closed system with rhenium from time t_0 to a later time will have an isotope ratio

$$\frac{O_s^{187}}{O_s^{188}} = \left(\frac{O_s^{187}}{O_s^{188}}\right)_{t=t_0} + \left(\frac{Re^{187}}{Re^{188}}\right)_{t=0} \cdot (e^{\lambda t_0} - e^{\lambda t})$$

For meteorites, t can be put equal to zero, and a plot of O_s^{187}/O_s^{188} against the ratio Re^{187}/O_s^{188} should yield a straight line. These ratios were determined experimentally for a number of meteorites and a straight line graph resulted. A sample from Witwatersrand yielded the smallest observed value of the ratio O_s^{187}/O_s^{188} and sets a limit on the possible primeval isotopic abundances of osmium.

R. D. Russell and R. M. Farquhar (Canada): Lead Isotopes and the Origin of Lead Ores.

The evolutionary patterns of the lead isotope ratios as they develop in the Earth through radiogenic additions seem now to be reasonably well defined. It is suggested that the well-known classifications 'anomalous' and 'ordinary' leads might represent the distinction between crustal and sub-crustal processes, respectively. As an example of this, it is shown that ores to which R. L. Stanton has ascribed a deep-seated and simple origin form the most regular growth sequence noted for any of the 'ordinary' leads. Precise intercomparisons of leads of this type from Broken Hill and Mount Isa have been made by F. Kollar. These show (a) a regularity even more pronounced than could be shown from previous, less precise analyses, and (b) a fine structure that can be interpreted in terms of the geological and geographical relationships of the samples. Unlike the case of 'ordinary' leads, 'anomalous' leads appear to contain lead produced under oxidising conditions where the thorium/uranium ratio is very variable.

V. Caglioti, C. Bettinali, A. Giardini and A. Mele (Italy): The Isotopic Abundance of Some Native Sulphur Deposits and Sulphur Minerals.

The S^{34}/S^{32} ratios of sulphides and elemental sulphur of several hydrothermal and volcanic deposits have been investigated. The sulphur isotopic abundance of native sulphur and associated sulphates of a typical geological formation have also been determined.

The sulphur isotopic ratios of the deposits studied are characteristic of the type of mineral formation.

F. R. Boyd (USA): Phase Equilibria at Pressures up to 90,000 Bars at 1600°C.

A single-stage hydraulic press has been constructed which will operate in the range 10–50

kilobars. A similar two-stage device is capable of operating to 100 kilobars. Both presses will operate to temperatures up to 1600°C, and in both cases it is possible to measure the temperature and pressure with reasonable accuracy. Diamonds have been synthesized with the two-stage apparatus at 75 kilobars, using the General Electric nickel catalyst system. The existence of the fayalite-spinel transition reported by Ringwood has been confirmed and the pressure-temperature curve has been outlined at higher temperatures and pressures.

O. F. Tuttle and P. J. Wyllie (USA): Carbonatite Systems.

A number of carbonatite systems have been studied both in nature and in the laboratory. The widespread natural occurrences of carbonatites has been noted by many and reviewed recently by Pecora. Some of the massive calcite-rich materials are in configurations reminiscent of volcanic plugs. These occurrences have mystified many geologists, for it was thought that high temperatures would be required to obtain a carbonatite magma. It has now been found that a carbonatite system can melt at a temperature as low as 650°C, provided that water and carbon dioxide are present. The liquid phase contains calcium hydroxide and calcium carbonate in addition to any dissolved carbon dioxide and water.

J. Wyart and G. Sabatier: Origin of Granitic Glass and Its Crystallization.

When the chemical compositions of typical sediments are compared with those of granites significant differences are noted. It is worthwhile to pose the question whether heating such sediments can result in material of granitic composition. When they were heated in the presence of water to temperatures not greater than 800°C changes in constitution were noted. Magnetite and hercynite remained unmelted and the liquid phase, when cooled, yielded portions approaching granitic composition as observed when examined in thin section.

G. Kullerud: Phase Equilibria in Sulphide System.

The problem of ore deposition remains one of the most puzzling and challenging topics for geochemistry. If this question is to be solved it will be necessary to have reliable information as to the pressure and temperature conditions prevalent during ore formation. A very extensive series of studies has been conducted of phase equilibria involving systems including: Fe–S, Cu–S, Ni–S, Ni–As, Cu–Fe–S, Fe–Ni–S, Fe–Ni–As, and others. Out of this has come a large number of experimental facts which can be used in geological thermometry. One that has been widely applied is the solid solution of FeS in sphalerite.

N. I. Khitarov (USSR): Water in Basaltic Magma.

Symposium: Radioactive Ages of Rock Systems
(July 27, 1960)

This symposium was sponsored jointly by IAV and IAS. The program was divided into three parts:

1. Meteorites: Ages and Relationship to Terrestrial Rocks.
2. Age Patterns in Metamorphic Rocks.
3. Ages of Precambrian Areas of the World.

Fifteen papers by 21 authors representing nine countries shows the wide interest displayed in these topics. Discussion was lively, and the symposium attracted a large audience.

Symposium: Island Arcs

Reported under Seismology.

Symposium: Ocean Floor

Reported under Physical Oceanography, *Topography, Morphology, and Geology of the Ocean Floor.*

Symposium: Volcanic Gases and Sublimates
(August 1, 1960)

In this all day symposium on Monday August 1, 1960, *M. Chaignau, R. Fabre,* and *H. Tazieff* (Belgium) presented an outstanding paper on the composition of lava of the Nyiragonzo Volcano, Belgian Congo, and, in particular, compared the compositions of occluded volcanic gases with the gases given off. Occluded gases were driven out on heating the rock to 800°C; they consisted of CO_2, CO, and SO_2; a small amount of CO_2 remained in the rock, but was driven off at 1000°C. *T. G. Sahama* (Finland)

provided an excellent petrographic description and chemical analysis of the rock.

The recent outstanding investigations by Japanese volcanologists, of volcanic gases and sublimates were described in two papers; one by *Iwasaki* and one by *S. Oana* (Japan) on the gases and sublimates from Showashinzan.

Geologists of the U. S. Geological Survey group in Hawaii gave a summary of recent studies at Kilauea. *S. Matsuo* also gave a paper on chemical equilibrium in the volcanic gases from the lava lake of Kilauea.

G. Imbo (Italy) summarized Italian studies on volcanic gases.

J. Green (USA) discussed the major features of volcanism on the Moon.

Symposium: Relations Between Volcanoes and Plutons

(August 3, 1960)

Of particular note in the all-day symposium on Wednesday August 3, 1960 was a paper on the comagnetic, volcanic and plutonic rocks of the Oslo region, and their origins, presented by *C. Oftedahl* (Norway). Both intrusive and extrusive rocks of the same composition occur in this area, and the field relations were delineated in detail, making an outstanding contribution to our knowledge of the behavior of single magma at different rates of cooling.

L. R. Wager (Gt. Britain) gave an excellent paper on the igneous cumulates from the 1902 eruption of La Soufriere on the island of St. Vincent.

S. I. Tomkeieff (Gt. Britain) summarized the geologic relations in British Tertiary lavas, and *A. G. MacGregor* (Gt. Britain) presented the results of recent researches (1954–60) on the British Tertiary igneous province.

M. H. P. Bott (Gt. Britain) discussed the geological and geophysical significance of negative gravity anomalies over granite masses.

J. G. Best (Australia) reported on the Cainozoic basaltic volcanoes in North Queensland.

Several papers by French investigators dealt with the relations between volcanoes and plutons in general, and in particular areas studied recently.

L. Glangeaud (France) summarized the fundamental relations between roots of volcanoes and plutons.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

SCIENTIFIC HYDROLOGY

General Report

The International Association of Scientific Hydrology held three symposia (nine sessions) in cosponsorship with IAM, IAPO, and SCOR, besides a symposium on Hydrological Maps, two plenary sessions on general and administrative matters, 20 open meetings of special Commissions, 5 open meetings of Committees, and 3 Council meetings.

The General Assembly at Helsinki highlighted, more than ever, the increasing role of international affairs of the AGU. About 30 hydrologists from the United States attended, 15 of them from non-federal organizations, a particularly gratifying showing probably attributable in part to the availability of NSF travel grants to scientists. Forty-seven papers in Hydrology, all of good quality, were given by American hydrologists. We met with prominent hydrologists from all parts of the world, many of whom were known to us from their writings or from previous meetings. As usual in such technical meetings there was a double-barreled profit; as much is gained from personal contacts and direct arrangements for exchange of data as from the formal presentations themselves.

OFFICERS

The officers of the IAH elected for 1960-1963 are as follows:

General Officers

President: W. Friedrich (West Germany)
Vice Presidents: G. V. Bogomolov (USSR)
C. A. Wallen (Sweden)
D. Tonini (Italy)
Secretary: L. J. Tison (Belgium)

Commission on Ground Water
President: G. B. Maxey (USA)
Vice Presidents: S. Buchan (UK)
R. Hazan (Morocco)
S. Mandel (Israel)
Secretary: G. Santing (The Netherlands)

Commission on Surface Water
President: L. Serra (France)
Vice Presidents: A. Volker (The Netherlands)
T. Gazzolo (Italy)
N. Simojoki (Finland)
Secretary: P. Kasser (Switzerland)

Commission on Snow and Ice
President: P. A. Shoumsky (USSR)
Vice Presidents: A. Bauer (France)
W. Field, (USA)
Morandini (Italy)
Secretary: W. H. Ward (UK)

Commission on Land Erosion
President: H. Kuron (Germany)
Vice Presidents: F. Fournier (France)
S. El Zein (Sudan)
Secretary: T. Maddock, Jr., (USA)

INTERNATIONAL SYMPOSIA

For the past few years, between the triennial General Assemblies, the IAH has conducted annual symposia on specialized subjects. These symposia are very profitable in that they afford opportunity for scientists in a single discipline to meet and talk about their subjects at a high level of competence, and they keep the IAH a viable organ. The practice is to be continued, and three IAH symposia are to be held by IAH during the two years prior to the 1963 General Assembly, as follows:

1. Ground Water, 1961, in Greece
2. Variations in existing glaciers, 1962, in Austria

3. Land erosion and geomorphology, 1962, in Italy

In addition, IAH will participate in the following with other organizations:

1. Symposium on climatic change, 1961, Rome (with UNESCO & WMO)
2. Conference on Equatorial Geophysics, 1961, Peru (with Peruvian Government Geophysical Institute)
3. International Cloud Physics conference, 1961, Australia (with Australian Academy of Sciences and CSIRO Division of Radiophysics)

The organization of the programs, deadlines for receipt of pertinent information, transmission of papers, and screening is in hands of the respective Commissions of the IAH, whose American representatives are the chairmen of the corresponding AGU committees. Secretary Wilson will advise the new officers of the IAH Commissions as to the names and addresses of these men; copies of all correspondence abroad should be sent to Secretary Wilson, Section of Hydrology, AGU. Also, all papers, when finally cleared by the respective AGU committee chairman, must be transmitted through Mr. Wilson.

IAH Budget

Receipts total about $38,000, of which the allocation from the IUGG is $14,000, the income from publications, $19,000, and about $5,000 is received from UNESCO and other grants. Virtually all is expended on publications; office and secretarial costs total less than $3,000.

However, Prof. Tison experiences grave difficulty in making both ends meet, and each of us can help, not only by purchasing copies of IAH publications, but by making these reports better known, and especially by making sure that our libraries subscribe to these. Each of us should make particular note that the publications of the IAH are virtually the only existing exclusively hydrologic journals.

IAH Bulletin

The IAH publishes a quarterly bulletin, which is available for an annual subscription of $3. The Bulletin solicits good articles for publication. There is no page charge. Subscriptions and papers should be directed to R. N. Wilson, Secretary for International Participation, AGU.

Screening—Considerable criticism was again voiced concerning not only the increasing number of papers presented at General Assemblies and published by the IAH with consequent excessive cost, but of the indifferent quality of many of the papers published. Excessive cost and questionable quality discourage sale of the publications. It was decided, therefore, to make the IAH publications more salable by reducing the bulk and improving the quality.

The Council of the IAH voted, therefore, that, in the future, national quotas will be established for the number of papers to be submitted at General Assemblies, and that all papers will be reviewed at the Assembly by screening committees, consisting of three members from each of the Commissions (Surface Water, Ground Water, etc.) before acceptance for publication. In order to avoid the embarrassment of having an undue number of papers rejected, it is incumbent on each country to review and screen its manuscripts before transmittal to the IAH. This, of course, has been and will continue to be the practice of the AGU.

Resolutions

The following resolutions were adopted:

1. WHEREAS the UNESCO in close cooperation with WMO is planning a symposium on climatic change to be held in Rome in 1961, with the following topics:

(a) Criteria for the termination of climatic fluctuation trends.

(b) Data requirements for determining climatic change.

(c) Technique, e.g., radio-carbon dating, dendrochronology, paleobotany, paleotemperature measurements, glacier fluctuations, etc.

(d) Theories of climatic change.

(e) Salient facts of climatic fluctuations.

(f) Implications of climatic changes for geomorphology, soils and ecology of plants and animals.

(g) Future research.

IT IS RESOLVED that the International Association of Scientific Hydrology wishes to participate in this most important symposium.

2. WHEREAS it is considered necessary to study the variations in existing glaciers,

IT IS RESOLVED that the International Association of Scientific Hydrology shall hold a symposium on variations in existing glaciers at Obergürgl in Austria during 1962.

3. WHEREAS the Huancayo Geophysical Institute, an official organism of the Peruvian Government, proposes that an International

Conference on Equatorial Geophysics be held in Peru in 1961 under the cosponsorship of IUGG, URSI, and CIG, and

WHEREAS the objective of the Conference would be to revise and discuss problems in equatorial geophysics, and to provide an opportunity to define areas of geophysical investigation for which the equatorial zones offer special characteristics for experimental programs, and

WHEREAS these characteristics provide opportunity for important work in hydrology, oceanography, and meteorology,

IT IS RESOLVED that the International Association of Scientific Hydrology wishes to participate in this most important conference.

4. WHEREAS an Ad Hoc Committee on Isotope Geology, Geochemistry, Age Determinations, and Radio-Activity of Rocks (CIGAR) of the Commission on Geochemistry has been established to consider its relationship with IUGG,

IT IS RESOLVED that the International Association of Scientific Hydrology has an interest in the work of the Ad Hoc Committee and requests to be kept informed of the proceedings of said Committee.

5. WHEREAS the Soviet National Committee of Geodesy and Geophysics has proposed the creation of a Committee for the Study of the Dynamics and Morphology of the Marine Littorals, and

WHEREAS the International Association of Scientific Hydrology has not hitherto been involved in studies of the above subjects, despite the many advantages to be gained from a knowledge of these phenomena,

IT IS RESOLVED that, in the event a Committee is established in IUGG to investigate these scientific matters, the International Association of Scientific Hydrology wishes to participate in its work.

6. WHEREAS the Australian Academy of Sciences and CSIRO are sponsoring an International Cloud Physics Conference to be conducted by the CSIRO Division of Radiophysics, to be held in Australia during September 1961, and

WHEREAS the organizers of the conference have expressed the wish that the Conference will come under the auspices of IUGG,

IT IS RESOLVED that, inasmuch as the International Association of Scientific Hydrology has a Commission on Precipitation and is very much interested in this matter, this Association wishes to participate in the Conference, providing the IUGG approves of such action.

Recommendations

1. The International Association of Scientific Hydrology expresses its wish to collaborate with the Committee of Terrestrial Tides in studying the question of the fluctuations of water level in wells under the influence of movements of the Earth's crust.

2. The International Association of Scientific Hydrology resolves to establish a committee which, whilst pursuing in particular the work hitherto of the Committee on Instruments, will extend its activities over the whole field of hydrometry. The Association offers the collaboration of this committee to the Commission for Hydrological Meteorology of the World Meteorological Organization.

The same offer is extended for the Committee on Standardization of the Association.

A recommendation by the USSR National Committee for the creation of an international association for Glaciology was referred to IASH. A special committee in IASH, appointed to consider the matter, met on July 26. Members were: H. Wilm (IASH), L. J. Tison (IASH), R. Finstersalder (Comm. of Snow and Ice), V. R. Ward (Comm. of Snow and Ice), Avsiuk (USSR), and Shumsky (USSR).

The above resolutions and recommendations were accepted by the Council, and are to be reported to IASH General Assembly then to IUGG Council.

SESSIONAL MEETINGS

COMMISSION ON SNOW AND ICE

Business Session, July 30

Ward stated conclusions of the special committee appointed by Wilm, to study the necessity for a separate association of glaciology, and consisting of Wilm, Tison, Shumskiy, Avsyuk, Finsterwalder, as follows:

1. No separate Association for Glaciology should be formed at this time;
2. The President of the Commission of Snow and Ice should be an *ex officio* member of the Council of IASH;
3. A symposium on variations of existing glaciers is to be recommended for 1962;
4. The National committees for Scientific Hydrology are urged to establish subcommittees for Snow and Ice, and national correspondents for the Commission of Snow and Ice.

De Quervain discussed the nominating procedures of IAH.

Finsterwalder presented his proposal that the

recording of glacier fluctuations be a permanent task of the Commission. This was followed by considerable discussion as to what should be measured, what are the fundamental objectives, and what sort of committee should be appointed to organize the task. A committee was appointed to firm up the proposal.

Robin discussed the future of the IGY World Data Centers. In the ensuing discussion it was noted that the archive function of the World data centers is important, but there have been very few requests for the interchange of data. *Robin* summarized the discussion with the observation that there appeared to be little strong sentiment for the continuation of World data centers.

Finsterwalder announced that a symposium 'Variations of Existing Glaciers' had been proposed for 1962. There appeared to be very strong interest in this symposium. After discussion the site of Ober-Gurgl, Austria, was chosen. Some sentiment was expressed for altering the name to 'Variations in the Regime of Existing Glaciers.'

Ward asked that each participating country name a national correspondent to the Commission on Snow and Ice if there were no national committee.

Finsterwalder presented nominations for officers of the International Association of Snow and Ice for the next triennium. The nominations were approved unanimously by the group. The names of new officers appear above, in the General Report.

Ward brought up for discussion the possible need to subdivide the Commission on Snow and Ice into three or more groups. No action was taken on this proposal, pending further discussion with the present and future officers.

Business Session, August 3

It was announced that, in response to Finsterwalder's proposal, a committee had been appointed to prepare a document by February 1 on an international measuring program for glacier fluctuations. The Committee consists of: Bauer, *Chairman*, (France); Finsterwalder, (Germany); Nye (Great Britain); Avsyuk (USSR); Kasser (Switzerland); Meier (USA); Solaini (Italy); Blachut (Canada).

It was announced that the officers were in favor of establishing four subdivisions of the Commission on Snow and Ice, to be

(1) Glaciers
(2) Seasonal snow cover (including avalanches)
(3) Sea, lake and river ice.
(4) Ground ice.

For subdivisions (2), (3) and (4), it was felt that persons should be appointed to encourage activity, and to organize a program for the next assembly. *De Quervain* was assigned this responsibility for (2), *Pounder* for (3), and *Bender* for (4). The need for such subdivisions was protested vigorously by several members present, but the consensus seemed to be that these subdivisions will be important in the future. Pleas were made that no simultaneous sessions be arranged.

Papers

Snow, Sea, and Lake Ice

Finsterwalder (*Germany*) opened the session with comments on the huge amount of work done on glaciology since the Toronto assembly, and the enormous success of the Chamonix Symposium. He noted that the future of glaciology is bright, and that some reorganization within the IUGG structure may be needed to cope with its expected growth. *Ward* noted with regret the passing of Past President Church. He mentioned the difficulty of arranging and scheduling such a full program and noted with appreciation that the Russian delegation had agreed to pare down their contributions to only the most significant.

Palosuo (*Finland*): *Crystal structure of brackish and freshwater ice.* He showed a strikingly perfect orientation of vertical crystal axes in brackish ice and a good horizontal orientation of these axes in ice of greater salinity. He attributed the change of orientation purely to salinity. This paper excited considerable discussion, with several authors pointing out that the Weeks and Pounder theories of ice crystal orientation might explain the phenomena without recourse to changes in salinity. *Glen* noted that the Weeks and Pounder theories would lead to disc-shaped crystals whereas those reported by Paluoso were, in fact, columnar.

Simojoki (*Finland*): *A long series of ice observations at Lake Kallavesi.* Differences in the

mean dates of freezeup and breakup observed since 1834 suggest that a marked climatic change was experienced about 1880.

Pounder (Canada): General properties of Arctic sea ice. Elastic properties of Arctic sea ice. Heat flow in ice sheets and ice cylinders. These three papers were read as one and presented a general discussion of growth, orientation, density, and elastic and thermal properties of Arctic sea ice. Sections through the sea ice revealed crystals having a chaotic orientation near the surface, vertical columns at depth, and slightly disordered crystals at the base. A persistent jog in the observed depth-salinity curve was attributed to changes in freezing rate with depth due to the effect of the air-ice boundary layer. Elastic properties were measured by a pulse-transducer technique. Compressional wave velocities could be measured very accurately, but shear waves were difficult to detect. Poisson's ratio was assumed in order to calculate Young's modulus, which appears to be a simple linear function of salinity. Frequency analysis provided some additional data.

Untersteiner (Austria): On the mass and heat budget of Arctic sea ice. This paper was a thorough exposition of the regimen and micrometeorological results at a station on the Arctic sea ice. It was noted that freshly bulldozed ice had an albedo of 0.38; within three days the albedo rose to 0.64 owing to weathering of the surface layer. One-third of the energy supplied to the surface in the summer was used to raise the temperature of the ice; the rest went into melting. Extinction coefficients computed from the temperature profiles agreed with those measured elsewhere by other techniques. This paper engendered considerable discussion.

Van Wijngaarden (Netherlands): Investigations concerning the transport of heat through a solid sheet of ice in periods of frost and thaw. This paper and the discussion which followed was concerned largely with the extreme difficulty in constructing and operating a reliable heat flow meter.

Price (Great Britain): The effect of the characteristics of snow fences on the quantity and shape of the deposited snow. This paper discussed studies of the size and shape of drifts deposited by snow fences of different orientation, height, and density ratio.

Gerdel and Strom (USA): Wind tunnel studies with scale model simulated snow. The elastic properties of the blowing material was of utmost importance in selection. Borax appeared to give best results for studies conducted at one-tenth to one-fiftieth scale. The coincidence of drifting patterns between scale model wind tunnel tests and field results was remarkably good. Considerable discussion followed on the importance of various scaling parameters such as Reynolds and Froude numbers.

SNOW ACCUMULATION AND OBLATION

Salamin (Hungary): Influence of topographic factors on the accumulation and melting of snow. The 'macroform,' orientation, and altitude determine the accumulation of snow; the relative importance of altitude depends on slope steepness and orientation.

Radok, Stephens and Sutherland (Australia): On the calorimetric determination of snow quantity. (Presented by *Gold.*) This paper was of great interest because it presented a potentially simple and accurate field technique for the difficult task of measuring the liquid water content of snow. One merely adds a 50 cc sample of snow to a cool mass of gasoline, causing the liquid water in the liquid snow to be frozen; the resulting temperature changes are due only to the small amount of liquid water and can be measured with relative ease.

Hattersley-Smith, Lotz, and Sayer (Canada): The ablation season on Gilman Glacier, Northern Ellesmere Island. This glacier has a negative regime according to studies of accumulation and ablation; the tributaries are retreating, but the terminus is not.

The following five papers presented results of the International Glaciological Expedition to Greenland.

Bauer (France), Glaciological studies of the International Expedition to Greenland; Precision of measurement of ablation. The first paper was a general resumé of the work. The second paper discussed a new type of ablation stake and the dispersion of measured values.

Hofmann (Germany): Tellurometer measurements on the Greenland Ice Cap during the International Glaciological Greenland Expedition (EGIG). High absorption of the electric wave by the snow surface, and constant temperature conditions, permitted great accuracy of tellurometer distance measurements. A network of

squares, 10 km on a side, was extended across Greenland (650 km). All sides and diagonals of each square were measured and the probable errors of measurement were determined by ignoring one of the side measurements. The total distance measured was 4,100 km. This was done in a field season of 3 months. The closing error per square was 3 to 4 cm, and the mean error in the whole distance was only 15 cm. Thus, glaciological results can be obtained from a remeasurement in only 4 to 5 years, a much shorter period of time than was previously thought possible. This paper elicited much favorable comment.

Mälzer-Möller (Germany): Leveling by the International Glaciological Expedition to Greenland (Presented by Hofmann). The field program was especially devised for a very rapid execution of conventional leveling techniques. Self-leveling levels were utilized, with level rods mounted directly on weasels; weasel settlement in the snow was measured. The 700-km lines on the ice cap were surveyed at a speed of 11.8 km per day and with a mean error per kilometer of 1.5 cm. In the crevasse zone the leveling was done on foot. The importance of these results in the analysis of velocities, strain rates, and accumulation in Greenland was noted in the ensuing discussion.

Ambach (Austria): The energy balance during a 10-day ablation period on the Greenland Ice Cap. Measured ablation was compared with that computed from micrometeorological results (energy budget) with good agreement. About 10 per cent of the incoming energy goes into heating the ice and 90 percent into melting. The amount of energy which goes into evaporation and condensation is negligible.

GENERAL GLACIER STUDIES AND GLACIO-METEOROLOGY

Kasser (Switzerland): Glaciological commentary on the new map of the Great Aletsch Glacier (1957, 1:10,000). This map shows crevasses and other graphical features as well as surface topography with unprecedented detail. By comparing the new map with older maps the marked thinning of the lowest reaches and equilibrium condition of the upper part of the Aletsch Glacier can be noted.

Avsyuk (USSR): Glaciological investigations carried out in USSR territory under the program of the IGY, 1957–59. This was a discussion in broad and general terms of the Russian IGY program.

Lliboutry (France): Buried glaciers and their morphological role. In the high Andes near Santiago firn may be covered with rubble and transferred to small glaciers, which occasionally sink more and more into the loose talus of the slope. These appear to be transitional between real glaciers and rock glaciers.

Gold and William (Canada): Energy balance during snowmelt periods at an Ottawa site. This heat budget study was done with simple instruments. A water equivalent of 13.4 cm was lost during the observation period, and it is estimated that 3.4 cm of this evaporated. In the following discussion it was suggested that the figure for evaporation seemed rather high and might have been due to the method of instrumentation and/or analysis.

Zanetti (Italy): Radiation temperature of the sky and ablation of ice. A method of calculation of the mean radiation temperature of the sky is given, and its use in ablation studies is suggested.

LaChapelle (USA): Energy exchange investigations on the Blue Glacier, Washington. A general description was given of the micrometeorological investigations at this IGY station in the Olympics. All factors except eddy conduction were measured directly. It was found that the eddy conduction could not be determined by either the Bowen ratio method or aero-dynamic relations. This was primarily due to the irregular wind velocity profiles.

Desio and Marussi (Italy): Topographical and geophysical results of the Italian Expeditions to the Karakorum 1953–55, with reference to certain glaciers. This paper was a broad general description of velocity and topographic measurements of several glaciers. The Lagally formula for glacier depth was used, which caused considerable discussion and some adverse comment from the audience.

RESPONSE OF GLACIERS TO CLIMATE

Finsterwalder (Germany): On the measurement of glacier fluctuations. A general report was given on detailed measurements of glacier topography made in the eastern Alps 1950–59, and recommendations were made for a broad worldwide program of similar nature. A zone

of thickening was seen to progress slowly to lower and lower altitudes. Many rates of surface rise or fall were quite small, and it was remarked in discussion that the effect of differing times of surveys relative to the end of the ablation season needed careful analysis.

Case (USA): Glacier-mapping activities in the United States. The IGY and IGC program of topographic surveying 9 glaciers in Alaska and 6 in Western United States was described.

Mercanton (Switzerland): Fluctuations of glaciers in Europe. (Presented by Kasser.) There has been little change in the percentage of glaciers which are increasing, stationary, or retreating in Europe during the period 1956–59.

Manley (Great Britain): Meteorological factors in the great glacier advance (1690–1720). Cold springs and cool summers in England seem to relate to a marked advance of glaciers in the Alps.

Ward (Great Britain): read a brief summary of glaciological activities in India.

Dolgushin (USSR): Recent glaciation of the Urals and its evolution. Glaciers in the Urals were discovered in 1945. They are active and are thought to be in equilibrium with the modern climate. Most of them are wind drift glaciers on lee slopes. They occur many hundreds of meters below the climatic snowline. Small changes in wind direction and speed have crucial importance in determining the glaciers' regimen.

Dolgushin (USSR): Glaciers of Central Asia and their evolution according to latest data. This paper reports on glaciers in the East Tien Shan and Nan Shan. The largest glacier in the Nan Shan is 10 kilometers long. These glaciers are very cold and the energy of glacierization is low. There are cases in which the upper glacier is thinning but 'Aufeis' in the valley below is thickening. The Tien Shan glaciers are in more rapid retreat, have a higher activity, and are more temperate in regimen.

Nye (Great Britain): The influence of climatic variations on glaciers. A nonmathematical summary of a theoretical analysis of the dynamics of adjustment of glaciers to climate, was given to show that the effects of climatic change are propagated down a glacier by 'kinematic waves,' and that the lower regions of glaciers are inherently unstable, and therefore extremely sensitive to climatic change. Some results of the theory agree completely with the thinning profiles found by Kasser on Aletsch Glacier. The complete mathematical derivation has just been published in *Proceedings of the Royal Society* and was not discussed. It was generally agreed by the members present that this paper summarized a major contribution to the field of glaciology. There was discussion of abnormal or sporadic glacier advances in Alaska and wavelike behavior in Antarctica where no ablation is present; these occurrences do not appear to be explainable by the Nye theory.

Meier (USA): Distribution and variations of glaciers in the United States exclusive of Alaska. This paper described the amount, location and present state of health of glaciers in the Western United States.

Suslov (USSR): Morphological pecularities and tendencies in the development of ice formation in the North-West Pamirs. Soviet research on the geomorphology, velocity, and state of health of Fedchenko Glacier was described.

Tonini (Italy): New observations on the Marmolada Glacier. A general description of the current research on thickness variations of the Marmolada Glacier was given.

Pounder presented a color movie on the freezing of water droplets.

GLACIER SURVEYING AND THICKNESS MEASUREMENTS

Blachut (Canada): The use of aerial photogrammetry in the study of mountain glaciers. Work on Salmon Glacier and on glaciers in Axel Heiberg Land served as a basis for recommendations for further photogrammetric work on glaciers. The importance of determining confidence limits was stressed. Accuracy approaching 10 cm per kilometer of flying height was attained. There was considerable discussion on targets for photogrammetry of glaciers and on the effect of ablation.

Weber, Sandstrom and Arnold (Canada): Geophysical surveys on Gilman Glacier, Northern Ellesmere Island (presented by Grant). A very comprehensive program of gravity, seismology, ice thickness and ice velocity measurements was accomplished. Calculations of the rate of discharge through a cross section showed values less than the measured ablation below that section. There was considerable discussion

on the interpretation of seismic elastic wave velocity depth profiles.

Shreve (USA): The borehole experiment on Blue Glacier, Washington. Hotpoint drilling, strain rates and inclinometer technique were described, as well as a preliminary interpretation of the strain rate-depth profiles. Some holes deformed in an irregular manner, whereas others showed the predicted smooth changes. In spite of considerable discussion as to the cause of this phenomenon, the explanation is still clouded in doubt.

Ward (Great Britain): Experiences with electro-thermal ice drills on Austerdalsbre 1956–59. This paper reported on a somewhat different approach to hotpoint drilling with similar results.

GLACIER FLOW

Allen, Kamb, Meier and Sharp (USA): Structure of the lower Blue Glacier, Washington. Foliation, a longitudinal septum, ogives and three different types of ice were described. The structures are primarily formed in an area of extreme compressive strain at the base of an icefall. It is not completely clear as to how the ogives are formed.

Kamb (USA): Ice petrofabric data in relation to the structure of Blue Glacier, Mt. Olympus, Washington. Detailed measurements of crystal orientation in different types of ice on Blue Glacier showed a very complicated pattern of behavior. The results are partly in accordance with the new thermodynamic theory of ice-crystal orientation.

Glen (Great Britain): Measurement of the strain of a glacier snout. Compressional strain was observed within 20 m of the glacier terminus, and the strain rate was greater in 1959 than in 1958 in spite of a retreating condition of the terminus.

Millecamps (France): On a new method of investigation in glaciology. This paper described the surface deformation and velocity changes during short intervals of time as measured by photogrammetry.

Aliverti (Italy): On the 'waves' of glaciers: observations along the length and at the front of the Lys Glacier (Monta Rosa). Wave ogives were described.

Haefeli (Switzerland): Contribution to the movement of ice sheets in Arctic and Antarctica. A detailed exposition of a theory for the motion of ice caps was given. The Glen flow-law, a horizontal bed, and no slip on the bed were assumed. The calculated surface profile agrees with the profile across Greenland, as measured by P. E. Victor, within an accuracy of 1 percent. It was shown that the height of an ice sheet is very insensitive to changes in accumulation.

Shumskiy (USSR): On the theory of glacier motion. An even more comprehensive discussion of the dynamics of ice cap flow was presented. Very few restrictive assumptions were made, so the results are in large part qualitative. It was shown that the equilibrium shape of an ice cap depends mostly on the intensity of accumulation and ablation, the relief of the bed and a coefficient of bed friction. Speed was shown to be proportional to the energy of glaciation, the slope of the surface, and the accumulation. Solutions were given for normal and tangential stresses in a glacier, the force of friction against the bed, the longitudinal profile, the velocity of flow, and the discharge. In the discussion it was generally agreed that this paper merited considerable study, as it presented a very useful and comprehensive picture of ice cap flow and introduced a number of important new concepts.

COMMISSION ON LAND EROSION

PAPERS

(July 29)

F. Fournier (France): An attempt to estimate the loss of soil from the Earth. Submits a map of areal rates of sedimentation based on precipitation and a relief ratio.

F. Bauer (France): Apparatus for the measurement of suspended matter.

J. Tizeront (Tunisia) Discharge of solids in rivers in Algeria and Tunisia. Reported extraordinarily high rates of sediment discharge—more than 2000 tons per square kilometer per year.

M. Van Wijngaarden (Holland): The influence of river works on the equilibrium of the river bottom in the vicinity of the bifurcations of the River Rhine in the Netherlands. A descriptive paper on theoretical and empirical model and field studies of the distribution of sediment by river distributaries.

N. Koroleff (Finland): Chemical composition

of lake water from Kallavesi, Finland. Presented chemical data on composition of the dissolved solids.

T. Gazzolo (Italy) and G. Bassi: Contribution to the study of soil erosion in drainage basins in Italy. Presented a map of soil erosion in Italy in millimeters per year, based on records of suspended sediment at 70 gaging stations.

H. Kuron (Germany): Long-term measurements of runoff and soil loss on three typical soils of Germany. Relationships are evolved between sediment yield from 16 square meter plots and rainfall.

T. Maddock (USA): Erosion control on Five Mile Creek, Wyoming. Erosion control works in a degrading stream, designed on sound principles, have proved highly successful in reducing erosion.

H. V. Peterson and R. F. Hadley (USA): Effectiveness of erosion abatement practices on semiarid rangelands in Western United States.

(Several abstracts were published reporting on Soviet work in erosion control in the Soviet Union. However, the authors were not present.)

COMMITTEE ON PRECIPITATIONS

Papers

(August 2)

G. Tschirhart: Notes on the temporal variation in precipitation. A description of the effect of geography and meteorology on storm rainfall, and of the variation of storm rainfall with time.

G. R. Kendall: The cube-root normal distribution applied to Canadian monthly rainfalls. Monthly rainfall data are well fitted to a cube-root distribution; confidence limits and a special plotting graph are presented.

Yves Brunet Moret: Method of analyzing the variation of precipitation according to time and space. Depth, area, and duration graphs are prepared for tropical thunderstorms. Storm intensity patterns are quite similar for all depths.

K. Heigel: The orographic variations of precipitation in "Hohenpeissenberg" Mountains. Notes a deficiency of precipitation in the forepart of the Alps, and an excess in the upper valleys.

J. Grunow (Germany): Mountain precipitation. Alter shields were found effective in plain and hilly areas as well as in mountain regions. Precipitation catch is decreased by 14 percent on windward side and increased by 10 percent on leeward side. This deviation can be eliminated by setting orifice parallel to slope.

J. Grunow: Variations in precipitation structure. Described a new rainfall-intensity gauge.

J. Jacquet: Small scale spatial variation in precipitation. Described a dense network of rain gauge observations.

A. Bleasdale: A compound rain gauge for assessing the errors of conventional rain gauge measurements. Described a compound 9-orifice rain gauge for use as a standard.

H. Schoeller (France): Mean isochlors of chloride content in rainfall in the Aquitane basin. Presented maps of monthly and annual isochlors of rainfall.

Symposia

Symposium: Low Water Supply and Periods of Drought

(July 26)

(The following papers were presented, or read by title).

E. Indrie: Low water flow curves for some streams in the Venetian Alps.

It is useful to make a first-hand experimental study of the bases for estimating presumed flow of a stream during periods of drought. The aim of the study is to determine probable sequence of discharges at low flow after a set time from a given situation or parameter, provided considerable precipitation does not occur in the interim.

Three streams in the Venetian Alps were studied—Cellina River, Boite River, and Cismon. Low water values read from the hydrographs were plotted as a single curve, and a point common to each river was established on the curve. When this point was found, it was possible to predict expected runoff after 10, 20, 30, or 40 days of drought. Equations giving discharge (q_i) for (t_i) days were established for each stream.

For practical purposes it is better to establish an empirical low-flow curve for each stream, from which curve it will be possible to calculate in advance the expected runoff during a low-flow period (drought).

S. N. Krinsky and M. F. Menkel: Methods of quantitative estimations of lingering droughts on rivers. (Author not present)

W. Lazzloffy: Examen des Basses Eaux.

Water planners must take into consideration the times of occurrence, durations, and recurrence intervals of periods of low flows. Unreliability of the lower part of the discharge curve must be taken into account, because of changes in bed configuration, vegetation, and other conditions. The basis for planning is generally the mean discharge of the dryest 5, 7, 10, or 15 days.

For purpose of estimation, a diagram is given which the relation ratio of long-term discharge ($\bar{Q}_m$) and average low water discharge ($\bar{Q}_{min}$) are plotted as functions of the surface area of the catchment basin. A map of lines of similar runoff is not applicable to areas of karst topography.

N. A. Baranoff and A. N. Popoff: Calculation of the minimum runoff in unexplored rivers of the Soviet Union.

(The authors were not present)

P. J. Wemelsfelder (The Netherlands): The persistence of river discharges.

A comparison was made between variability of precipitation and discharge. *Variability of precipitation* is classified (+) or (−) in relation to the long-term mean for that month. Thus for a period of (A) years.

12 A $(\frac{1}{2})^{pA}$ where $\frac{1}{2}$ = 1 chance in 2 (+) or (−), and p = months.

The mean value of precipitation has no relation to the *variability of discharge.*

For a study of the Rhine at Lobith:

43 per cent of months were (+), that is, they exceeded the mean, and 57 per cent of months were (−), that is less than the mean.

The mean length of the 6 longest (continuous) periods of (+) or (−) precipitation was 8.5 months.

The mean length of 6 continuous months of (+) or (−) discharge was 20 months. Therefore:

$$\frac{20}{8.5} = 2.5 \text{ times greater length + or − discharge.}$$

Thus, the persistency of river flow, either (+) or (−), is greater than the (+) or (−) precipitation relating to that flow. The main cause is storage capacity of the river. In the 41-year period 1919–59 for the Rhine at Lobith, ⅔ of the time of discharge was 'persistent.' Persistencies continued quite independently of seasons of the year. Occurrences of persistencies are regarded as products of chance.

For the study of the Rhine, the quantity of snowfall in the mountains has little or no influence on the occurrence of persistencies.

The tendency of the river is to produce more easily and frequently (−) persistencies than (+) persistencies.

O. Dub: La definition des bas debits et leur répartition spatiale. (Author not present)

J. Beretin: La variabilité des precipitation et des secheresses en consideration du besoin. . . . (Author not present)

J. J. de Aspuru: Les sequiajes del Duero (Author not present)

(July 27, A.M.)

J. V. Sutcliffe, and W. R. Rangeley (Great Britain): Variability of Annual River Flow related to Rainfall Records.

Russell G. Mann (USA) and E. M. Rasmusson: Extended Low Flow Forecasting on the Mississippi River.

J. Rodier (France): Extension de la secheresse exceptionnelle observée en 1958 dans les regions equatoriales.

Allan Siren (Finland): Occurrence of Low Discharge Periods in Rivers in Finland.

Marco Vesentini: Les Grands Étiages du Po.

I. Zsuffa: La prévision à longue échéance du débit des rivières de la Hongrie en periodes sèches.

E. A. Johnson (USA) and H. G. Meginnis: Effect of Altering Forest Vegetation on Low Flow on Small Streams.

R. W. Bailey (USA) and Otis L. Copeland: Low Flow Discharges and Plant Cover Relations on Two Mountain Watersheds in Utah.

G. Tison: Coefficients d'écoulement et perméabilité-courbes de Tarissement.

The papers ranged over a considerable field. Geographically the areas described included Europe, America, Africa, and New Zealand.

The approach to solutions of the problem of low flows, depending on the purpose of the studies, might be based on a physical analysis, or on a statistical approach that might be more or less empirical.

In the discussion members raised many questions to which the answers are not yet known,

and it would appear profitable to include the same general topic in a future Assembly, perhaps six or nine years hence.

(July 27, P.M.)

Huff and Changuin: Droughts in Illinois. These appear greatest in the southern part of the State where, paradoxically, annual rainfall is greatest. The droughts appear to be associated with patterns of atmospheric stability over the United States.

W. Van der Bijlad Berk: Drought periods at Manhattan, Kansas.

Roche: Method of estimation of low-water discharges. Described a method of extending a record of stream flow observations by use of rainfall records and recession curves.

A. H. Laycock: Drought Patterns in the Canadian Prairies. Followed Thornthwaite's procedures on moisture deficiencies and gives data on average, maximum and minimum deficiencies, in inches. Finds that Thornthwaite and Lowry-Johnson yield the same results, if Thornthwaite soil moisture storage is adjusted.

L. Serra: Characteristics and Meteorological Causes of Droughts.

G. S. Benton: Quantitative Relationships Between Atmospheric Vapor Flux and Precipitation. Geographic distribution of precipitation is proportional to the atmospheric movement of vapor and a characteristic length. For large areas, ratio of total precipitated water to vapor inflow varies as the square root of the area. In North America about one third of vapor inflow falls as precipitation.

SYMPOSIUM: TIDAL ESTUARIES
(See also under Physical Oceanography; July 28)

J. Grindly: Determinations of the salinity of water in estuaries.

Discussed a method of extrapolating the measurement of chlorinity to total salinity of water in estuaries.

G. Tison: Relation of discharge to salinity in a tidal river.

J. C. Shonfeld: Mechanism of longitudinal diffusion in a tidal river—there is a maximum.

F. Santema: Water management in The Netherlands.

The salt load of the Rhine is steadily increasing, owing to industry, salt mining, and other activities of man.

A. G. Wiersma: Water management in Deljland.

A. Klein: Movement of mud in a tidal stream measured by radioactive diatoms. There is evidence of an upstream drift of mud.

H. Schulz and G. Strohl: Studies of the movement of sediment by means of radio isotope Cr^{51}.

Described a useful technique for tracing the complex movement of sediment in tidal estuaries, the technique is probably applicable to rivers, generally.

C. P. Lindner: Currents in tidal reaches of rivers and their effect on shoaling of Side Basins.

Fine-grained sediments tend to be trapped in the salt water wedge, which leads to shoaling.

R. Binnefille and A. Warluzel: Studies comparing the dynamics and the Coriolis Force in shallow seas.

It was shown that the Coriolis Force is important in tidal propagation.

K. F. Bowden: Circulation and mixing in the Mersey estuary.

Measurements of velocity, temperature, and salinity were made to determine the flow pattern, the salinity and the density gradients. At flood tide vertical mixing was essentially complete.

D. W. Pritchard and J. H. Carpenter: Measurements of turbulent diffusion in estuarine and in shore waters.

Reported on the use of the fluorescent organic pigment, Rhodamine B Tracer.

D. Harleman and A. T. Ippen, The turbulent diffusion and convection of saline water in an idealized estuary.

An experimental and theoretical study of the basic factors that determine the distribution of salinity in a partly mixed or well mixed estuary.

SYMPOSIUM: ANTARCTICA
(Session I, August 1)

C. J. Lorius (France): Studies of accumulation at Adelie Land. Precipitation was found to be proportional to the slope and inversely proportional to the distance from the coast.

C. J. Lorius (France): Deuterium content of precipitation in the Antarctic and its application to the problem of dating névé layers. Deuterium content is proportional to temperature, and pre-

cision of laboratory technique was sufficient to estimate the temperature of the cloud base to within ± 2 degrees.

Picciotto (Belgium) gave a short report on similar isotope studies at Roi Baudoin. Radiosonde temperatures, and deuterium and oxygen temperatures, were compared for a whole year, and the two curves were very similar. The total range of temperatures within a cloud was found to range up to about 10 degrees but the isotope data proved to be an excellent thermometer for the middle troposphere.

S. Epstein (USA) summarized his work on oxygen isotopes and presented a discussion of some of the difficulties inherent in collection and interpretation.

Goldthwait and Cameron (USA): The US-IGY contribution to Antarctic glaciology. Curves of equal net accumulation were drawn for Antarctica. A total accumulation of 1.7×10^{18} grams per year was computed. This result agrees exactly with the figure obtained by Mellor.

T. L. Péwé (USA): Multiple glaciation in the McMurdo Sound region, Antarctica; a progress report. Four major Quaternary glaciations are recognized in the McMurdo Sound region. The last occurred at least 6,000 years ago.

A. Bauer (France): A new estimate of the volume of the ice in the inland ice of Antarctica. The inland ice of Antarctica, estimated at about 30,000,000 cubic km in volume, has a mean altitude of 2,175 m above sea level, and a mean thickness of 2,300 m. It was noted in the discussion that the volume of the ice cap had been estimated by Crary at 26×10^6 cubic km, and by the Russians at 28×10^6 cubic km.

H. C. Hoinkes (Austria): Studies in glacial meteorology at Little America V, Antarctica, 1957. The results and difficulties of a comprehensive micrometeorological program were explained. It was shown that it is impossible to record albedo and net radiation directly because all instruments available today have calibration factors that depend upon solar altitude, cloudiness, and temperature. The average albedo during the summer was 0.89. In winter the main heat supply occurred during two storms.

A. Cornet (France): Displacement of Astrolabe Glacier. This was a discussion of geodetic means of determining glacial displacements.

(Session II, August 2)

L. D. Dolgushin (USSR): Zones of snow accumulation in eastern Antarctica. It was found that the accumulation in East Antarctica is very sensitive to slight changes in slope and to the presence or dying out of katabatic winds. The maximum accumulation (600–700 mm) occurs as the katabatic winds abate rather suddenly near the coast. At a distance of 150 km from the coast the katabatic winds are strong and only two percent of the 150 to 250 mm precipitation remains after erosion. The accumulation at distances of 800 km and more from the coast is on the order of 50 to 60 mm; approximately half of this accumulation is due to hoar frost.

W. W. Vickers (USA): The use of statistical analysis for tracing of firn layers in Antarctica. Standard statistical parameters were derived from about 10,000 grain-size measurements using an IBM 650. These parameters were used to prove or disprove correlations from one station to another of snow layers. In some cases layers could be traced with statistical validity over considerable distances. However, there was some discussion as to whether cyclonic storms could have such wide geographic extent.

Dingle and Radok (Australia): Antarctic snow drift and mass transport. (Presented by Bender.) Transport of drift snow is a complicated function of wind velocity and elevation. The drift density is an exponential function of the reciprocal of the wind velocity at each height. A simple power law function does not apply over a large range of height.

Kotlyakov (USSR): The results of study of the processes of formation and structure of the upper part of the ice sheet in Eastern Antarctica. (Presented by Shumskiy). Results similar to those presented by Dolgushin were noted, with increased discussion of the density of the accumulation.

Kotlyakov (USSR): The intensity of nourishment of the Antarctic ice sheet. (Presented by Shumskiy.) A total transfer of accumulation of the calving margin is 1,210 cubic km per year; the edge of the ice sheet contributes 22 percent, the ice shelves contribute 43 percent, and ice streams contribute 35 percent. Melting from the lower surfaces of ice shelves totals 120 cubic km. The total loss thus is 1,330 cubic km, but this is compensated by a net accumulation of

2,550 m. Thus the Antarctic ice sheet must be growing. In the ensuing discussion it was noted that sea level is rising at the present time, which would suggest a diminishing ice sheet. However, heating and thermal expansion may account for this apparent rise. It was also suggested that all Antarctic data are somewhat biased because logistical considerations were important in the selection of observation sites.

Sugara (Japan): Salt composition of snow, ice and pool water samples collected in Antarctica. This is a general discussion of the occurrences of Na, K, Mg, Ca, Sr, Cl, SO_4, I, P, and As in water samples collected near Showa Base.

Wexler (USA): Growth and thermal structure of the deep ice in Byrd Land, Antarctica, (presented by Ostapoff). This represents an improved model of the growth of the ice sheet in West Antarctica, starting with a water-filled trough between the Ross and Bellingshausen Seas. The theoretical model can be used to predict time of formation, internal temperature distribution, and ice flow.

Jenssen and Radok (Australia): Transient temperature distributions in ice caps and ice shelves. (Presented by Ostapoff). It was found that the character of the temperature depth curve was due largely to the effect of ice motion and not climatic change.

C. R. Bentley (USA): Glaciological results of traverse geophysical observations in West Antarctica. This paper gave results from seismological, gravimetric, and topographic studies on traverses in West Antarctica. A rather detailed map of the subglacial topography was presented. There appears to be a slight reflecting layer within the ice, but data that could be obtained were insufficient to determine the character of this layer. No correlation of surface slope with thickness was apparent; a conclusion which prompted considerable discussion.

E. C. Thiel (USA): Results of the 1959-60 airborne traverse. An airborne traverse involving seismic soundings, glaciological studies, elevation, weather, gravity and magnetometer studies was reported. It was found that there is no evidence for a broad connection between the Ross and Weddell Seas, except along a possible narrow ice-filled gorge. Considerable data were presented on the structural geology of West Antarctica.

Crary and Van Der Hoeven (USA): Sub-ice topography of Antarctica, longitude 160° W to 180° E. More details on the sub-ice topography were presented in this paper. The Antarctic horst and the structure of Victoria Land were described.

C. Rouillon (France): Thickness of a glacier cap in Adele Land. Gravity measurements and their application to determining ice thickness were discussed.

Bender and Gow (USA): Deep drilling in Antarctica. A hole was drilled through the Ross Ice Shelf to a depth of 254 m after the initial success of drilling a 308 m hole at Byrd station. Stratigraphy was visible only to a depth of 120 m, which at Byrd station was accumulation of the year 1547. Diesel fuel instead of compressed air was used as a drilling fluid at the bottom of the Ross Shelf hole.

Zumberge, Giovinetto, Kehle and Reid (USA): Glaciological studies of the Ross Ice Shelf. The strain rate pattern and the accumulation pattern were measured over a series of firn anticlines and transverse crevasses in the Ross Ice Shelf. The firn stratification gave insight as to the time of origin of the anticlines. The strain rate data defined a rough fracture criterion.

Twelfth General Assembly
International Union of Geodesy and Geophysics

Helsinki, Finland, July 25-August 6, 1960

INTERNATIONAL COMMITTEE OF GEOPHYSICS (CIG)

An informal meeting of the CIG was held on the evening of August 4, 1960, at Helsinki. The topics of discussion included the future solar patrol, world magnetic survey, geophysical program during solar activity minimum, upper mantle project, world data centers, and 1961 world days calendar.

A proposal for future cooperation in solar physics, with particular reference to solar patrols, submitted by Professors Ellison and Minnaert was endorsed. This would call for activity on the part of 10 to 15 stations in contrast to the 19 cinematographic and 25 visual stations in the IGY program. Tabulated lists of flares, active prominences, etc., would be sent to World Data Center C with copies to WDC-A and WDC-B. Publication would be made by the *Quarterly Bulletin*, and the IAU was called upon to expand publication to include such new material as photometric observations and solar disk magnetograms of Mt. Wilson. A group consisting of Shapley (convener), Elvey, Poushkov and Laursen was asked to study the matter further, and to report to CIG by January 1961.

At its second meeting (Paris, March 1960), the CIG endorsed the World Magnetic Survey, and the proposal that joint studies in adjacent fields, particularly in those that involve solar-terrestrial relations, should be conducted at solar activity minima. The IAG plans for the World Magnetic Survey, as developed at Helsinki, are to be supported by CIG. As to the adjacent studies at sunspot minimum, a working group, consisting of Beynon (convener), Ellison, Nicolet, Vernov, Elvey and Laursen, was established to look into a program that might be undertaken, and to report to CIG prior to January 1961.

Professor Beloussov, President of CIG, proposed a program for the study of the upper mantle, embracing such topics as deep drilling, development of deep-sea seismograph for exploring the upper mantle beneath oceans, studies of deep-focus earthquakes to find mechanisms of strain release in the upper mantle, magnetic and gravimetric studies to explore variations in the upper mantle, studies of tectonic and magmatic development of the crust, theoretical studies of phase changes, thermal conditions, equation of state, processes of differentiation and movement, and high-pressure laboratory studies of rock behavior. A working group consisting of Beloussov (convener), Press, Nagata, and Tardi of CIG and a co-opted membership of the IAS (Ewing, Rittmann, Magnitsky, Heezen, Tsuboi, Runcorn, and Riznichenko) was asked to study the proposal prior to the next meeting of CIG.

Activities of the World Data Centers were reviewed, and the CIG will act as becomes necessary to expedite the completion of data interchange. Corrected station lists are being compiled, which will assist in the completion task. The discipline members discussed current needs and criteria for continued data interchange. In the light of these comments, indicating changes and reductions in data interchange as recommended by specialists, the CIG Secretary-General will draft a new Guide. In this connection, the following criteria were agreed to as necessary for the establishment of new, or the continuation of old, World data centers: (i) collection of data in accord with the CIG Guide, (ii) exchange of data according to the Guide, (iii) supplying of data on order from scientists or institutes at cost, and (iv) availability and accessibility of data at centers on request.

The definitive World Days Calendar for 1961 will be established in September at a meeting

of the International World Day Service. Shapley reported that the calendar will be similar to that for 1960.

The following report on publication of the *IGY Annals* was presented: Volume X, Fifth Meeting of CSAGI, has been passed for press. Volume XI, Fifth Meeting of CSAGI (Symposia), awaiting page proofs. Volume XII a and b, First Results of IGY Rocket and Satellite Research, some page proofs with editors, some pages passed for press. Volume XIII, Part 1, Ozone Manual, galley proofs with printers; Part 2, IGY Calendar Record, tables with printers, text to be sent to printers before the end of August. Volumes XIV and XV, IGY Ionospheric Data, tables with printers expected to be passed for press in September. Volume XVI, Oceanographic Volume, part of manuscript received from contributors.

Participants included V. Beloussov (President), G. Laclavère (Secretary), L. V. Berkner, B. Bolin, C. T. Elvey, V. Laursen, T. Nagata, M. Nicolet, H. Odishaw, Frank Press, G. de Q. Robin, A. H. Shapley, J. Van Mieghem, J. Bartels, R. Fraser, P. Hart, and N. V. Poushkov.

Reviews

K. WADATI (Supervisor), K. TERADA (Editor-in-Chief), *Encyclopedia of the Oceans* (in Japanese), Tokyo-dou, Tokyo, 671 pp., 13 plates, 10 color plates, 1960, $6.00.

This work began as a result of a meeting of I. Oohashi, representing the publisher, and K. Wadati, Director General of the Japan Meteorological Agency and his staff oceanographers. In the fall of 1958 a board of editors was formed, the necessary contributors were found and work began. By April 1960, the 671-*Encyclopedia* was off the press. According to my sources, at least 50 % of the effort was spent in 'spare time' and no direct support came from the government, though there was certainly indirect support inasmuch as 7 of the 9 editors, and 10 of the 30 contributors, as well as the Supervisor and Editor-in-Chief, are of the Japan Meteorological Agency.

In reviewing this book, it must be kept in mind that it was written by Japanese for their own use. For example, the entry 'Adjacent Seas of Japan' is 20 pages long. It might be argued that a 20-page entry is out of proportion for a book of this type, but all Japanese oceanographers will doubtless welcome this succinct description of their own waters. Although the *Journal of the Oceanographic Society of Japan* has a policy of writing all captions and legends of tables and graphs in English, making it possible for more people to get some benefit from the Japanese articles, this book does not do so. Titles of entries appear usually in Kana (a kind of Japanese alphabet) followed by the equivalent in Kanji (Chinese characters), which, in turn, is followed by the English equivalent. Where English words appear in the text, they are generally subject to the Orientals' disregard for syllabification. For example, in one place 'angular sp-' appears at the end of one line, and 'reading' starts the next line below. Too much reliance on old dictionaries has produced some perfectly correct but amusing entries such as 'Vulgar establishment.' There are a few minor irritations, such as the table on composition of artifical sea water, which begins at the bottom of page 305, and is continued on the other side of the page.

The editors seem to have been successful in maintaining a reasonable balance of subject matter. A large section is devoted to marine bacteriology; zoology and botany seem to be represented by numerous entries on specific subjects; coastal engineering, navigation, exploration, ships, and biography are well represented. As might be expected, physical oceanography occupies the major portion of the book, but, fortunately, it does not dominate. A careful search revealed practically nothing on turbulence—a puzzling matter until it was realized there is very little mathematics in the book; even so, the neglect of turbulence is a weakness that should be corrected in the next edition. Acoustics, likewise, is not given much space. A serious fault, too, is the lack of scientific names for fish and birds, although sea-weeds and plankton properly are given Latin names. On page 251, mention is made of *Salt water venomous catfish*. Is this our *Galeichthys*? We will never know and further, the Japanese will never know, either, until Latin names can be compared. Page 530 has the entry *Buri* with *Yellow tail* as the English equivalent; the number of fish with this common name must be in the hundreds. Page 553 contains the entry *Head fish* and an accompanying drawing, which is obviously *Mola mola*, which we call 'ocean sunfish.' This is another possible source of confusion.

Ten appendices contain material on tidal harmonic constituents, mean monthly water temperatures at various ports in Japan and the United States, morphometry of the oceans, oceanographic research establishments of the world, research vessels, books and journals on oceanography, chronology of oceanographic discovery and research, and forms and characteristics of sea ice. Finally, there is a 35 page index.

Inasmuch as we have no such encyclopedia in English, we have learned to get along without one, and until the reviewer received this copy, he never gave much thought to the need or potential usefulness of one. Now that a copy of this work is on his desk, even though it is in a difficult language, the value of such a reference book becomes more apparent every day. During a normal day's work, many questions come to mind but are left unanswered, either because there is no time to hunt through many books or because the proper book may be in the library or elsewhere. Questions such as—What was Secchhi's full name? When was the first Nautilus Expedition? Where is Ocean Weather Station PAPA? arise constantly. Some are due to idle curiosity and others are urgent. An encyclopedia will provide a ready answer. The Japanese now have one and we do not.

This book is further evidence of the initiative, energy and devotion of Japanese oceanographers. Once they realized the need for such a book, it was written and published in less time than many of us would need to fill out the necessary forms for approval and funds.

F. C. W. Olson

J. A. RATCLIFFE, (ED.), *Physics of the Upper Atmosphere*, Academic Press, New York and London, 585 pp., 66 tables, 167 figures, 1960, $14.50.

This book is a readable and carefully organised treatise on the upper atmosphere. Professor Ratcliffe is a leader in this field, and with unerring

judgment has selected the best authors for the various chapters. The upper atmosphere is investigated for the purpose of obtaining knowledge of its composition, temperatures, winds and changes, and of its luminous, electrical and magnetic effects at all altitudes and at all points of the Earth. Many direct measurements have been made by means of rockets to 250 km, and a few at much greater heights, by satellites. Each chapter is complete in itself and is helpful to the other chapters; there is little overlapping of material. Each chapter has a full set of references up to December 1959. A complete author and subject index is provided.

In Chapter 1 Chapman gives a general description of the known facts of the atmosphere to about 250 km, and quickly ascends above this to interesting theoretical consideration of the outer regions that merge into interplanetary space and the solar corona. These regions may be at a very high temperature and populated mainly by hydrogen.

In Chapter 2 Nicolet constructs a model of the atmosphere from rocket data to 200 km, and brings out the uncertainties in the model because rocket data of the air density at 100 km vary by a factor of 4. This causes great variations when extrapolation is made to greater heights. He presents satellite measurements of air density to 750 km, and shows that many atmospheric models will account for these densities because of uncertainties lower down.

In Chapter 3 Newell summarizes all rocket data of air density, composition, ozone, ions, airglow, aurora particles, cosmic rays and micro-meteors.

In Chapter 4, Friedman gives a fine account of the energy and depth of penetration of the wavelengths of the solar spectrum into the atmosphere, and of the ion counter techniques used to measure this. He describes the X ray spectrum of the corona, and the emissions from solar flares. He outlines how the solar emissions form the ionosphere for a quiet Sun, and how the emissions and ionosphere change when the sun becomes active.

In Chapter 5, Bates describes the airglow, its spectrum and altitude, the excitation processes, and the theories of its origin. The source of the energy of the air luminosity has been attributed to incoming particles from the Sun or from space, to atmospheric winds, and to solar energy absorbed during the day and emitted during the night, but at the present time no complete theoretical explanation has been worked out.

Chapters 6 and 7 on the aurorae are by Bates. The first gives a complete account of the observed facts of the aurora—its position in space, distribution over the Earth, motions, its changes with the day, year, and with sunspots, and its changes with geomagnetic variations. Chapter 7 describes the auroral spectrum, and the theories that have been proposed to explain its variations. No final conclusions are reached because of the lack of knowledge of reaction rates. The chapter is a valuable clarification of a complex subject.

Chapter 8, by Booker, deals with radar studies of the aurorae. The radar method has an advantage over visual observations in that it can be used in the daytime and in cloudy weather. It is limited, however, in that it discloses patches of auroral ionization only from directions approximately perpendicular to the Earth's magnetic lines of force. On the whole, the radar and visual location of aurorae agree, when comparison is possible, but many facts observed in the radar auroral experiments remain to be explained.

Chapter 9, by Ratcliffe and Weeks, is practically a book about the ionosphere. It is clear, complete and authoritative, and should be first on the list of any one who wishes to study the subject.

In Chapter 10, Vestine describes the variations in geomagnetism. These are believed, almost with complete certainty, to be caused by electric currents in the ionosphere. The changes in the Earth's magnetic field in periods of both magnetic calm and storm are outlined, and the patterns are drawn of the ionospheric electric currents required to produce the changes. The several theories of the causes of the electric currents are discussed but no final conclusions are reached.

Chapter 11, by Greenhow and Lovell, deals with meteors and their effects on the upper atmosphere. They show that, although the major meteor showers supply prominent visual phenomena, their contribution to the total amount of meteor flux is much less than that from the sporadic contribution of small meteors. For example, meteors of magnitude greater than 9 contribute about 200 kg entering the entire atmosphere per day, and the smaller meteors bring in about 800 kg per day. Their energy is dissipated in levels from 60 to 110 km, and is not sufficient to add much to daytime E ionization, but may account for sporadic E at night. From the drift of meteor trains, various complicated wind patterns in the atmosphere were determined.

Chapter 12 records very briefly some of the advances made during the International Geophysical Year from July 1957 to December 1958.

E. O. Hulburt

A. P. VINOGRADOV, *The Geochemistry of Rare and Dispersed Chemical Elements in Soils*, 2nd Edition, Consultants Bureau, Inc., New York, 209 pp., 1959, $9.50. (Translated from Russian)

This revision proposes to bring up-to-date a book published eight years ago. It involves additional data obtained in the laboratories of the USSR, particularly from the laboratories of the Vernadskii Institute of Geochemistry and Analytical Chemistry, and some data from sources outside of the USSR, but no attempt is made to cover all of the literature pertaining to the topic. In the author's words, "The bibliography consists of a list of scientific works which have recently become well known and which contain the most important data." The most recent non-Russian literature cited is one paper published in 1954, but Russian literature as recent as 1957 is cited.

The elements discussed are the conventionally considered rare ones: Br, F, I, As, Se, (Te), Li, Rb, Cs, Rare Earths, Y, Zr, (Hf), Cd, Ra, Io, Th, V,

and others that, in small amounts, are normally found in soils, namely, Sr, Ba, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Pb, (Sn), Mo, and W.

Following a short introductory chapter on chemical ecology, a chapter gives, very briefly, the analytical method used for the estimation of each element studied. This is followed by a chapter that summarizes the geochemical principles involved in the distribution of rare elements, including the role of organisms. Following a brief discussion of the soil-forming rocks and soils of the eastern European plain, succeeding chapters are devoted to single elements, or families of elements, as determined by their grouping in the periodic table, although arsenic and selenium are discussed in the same chapter. Each of these chapters presents such data as are available on the content of the element in soils from different localities and from different horizons. The data are complete for 20 soil profiles from soil zones of Eastern Europe, and incomplete for soils from other regions, including many from outside Europe. The chapters vary in length from twenty-two pages for fluorine, bromine, and iodine, to less than four pages for yttrium and the rare earths. Two brief final chapters consist of a presentation and discussion of the *Geochemical Regularities in the Distribution of Rare Elements in Soils*, and a summary consisting chiefly of a table comparing the average content of the elements in soils with that in different types of rocks.

The book is a good addition to the literature of geochemistry and represents a good, but incomplete, collection of the published information on the occurrence and geochemical behavior of the rare and dispersed elements in soil.

Charles R. Naeser

A. A. Smales and L. R. Wager, (Eds.), Methods in Geochemistry, Interscience, New York, 464 pp., 1960, $13.50.

The book contains 11 chapters by 12 authors from Oxford University, the Atomic Energy Research Establishment at Harwell, and the University of Cape Town. The purpose is to provide geochemists with accounts of the methods available for the analysis of natural materials. After a useful chapter, by L. R. Wager and G. M. Brown, on the collection and preparation of material for analysis, each succeeding chapter gives briefly the principles involved, but is concerned mainly with techniques of the methods and their geochemical applications. The methods discussed are: Spectrochemical analysis, by S. R. Taylor and L. H. Ahrens; X-ray fluorescence spectrography, by H. I. Shalgosky; Stable isotope geochemistry and mass spectrometric analysis, by K. I. Mayne; Mass spectrometric isotope dilution analysis, by R. K. Webster; Radiochemical methods, by S. Moorbath; Radioactivation analysis, by D. Mapper; Polarography, by S. Moorbath; and Chemical separations (ion exchange, solvent extraction, and paper chromatography), by F. W. Cornish.

An additional chapter by E. A. Vincent differs from the others in that it does not attempt to cover completely the well-known 'conventional' gravimetric and volumetric chemical methods. Instead, it is devoted to some of the more recent developments, such as flame photometry, colorimetric methods, and the rapid analysis of silicate rocks.

The book should be of great value to both geologists and chemists. It is not only authoritative, but clearly and simply presented. Despite the attention given to details of technique, its principal value may well prove to be for geologists, who can learn from it the range of applicability and the limitations of these modern methods, and who may be able to choose more discerningly the methods best suited to their problems.

There are but very few references to the enormous Russian literature; perhaps the authors and editors felt that these would have been of little value because of the language barrier.

Michael Fleischer

Philip H. Abelson (Ed.), *Researches in Geochemistry*, John Wiley & Sons, New York, x + 511 pp., numerous tables, 126 figures, 3 plates, 1959, $11.00.

A collection of 23 articles in the modern approach to geochemistry by 25 authors, that were presented in seminars at the Geophysical Laboratory of the Carnegie Institution of Washington and at the Johns Hopkins University, in an effort to "keep (the respective laboratory staffs) abreast with the developing frontier of geochemistry." This marvellously conceived book has, in addition, achieved its end outside the institutions in which the seminars were held. It is replete with new data, new ideas, and invigorating discussions. For some of the articles that are reviewed, a succinct treatment in a surprisingly clear presentation has been attained. The topics presented are as follows:

Sedimentation on the Ocean Floor, by G. O. S. Arrhenius
Rates of Geochemical Reactions at Low Temperatures and Pressures, by R. M. Garrels
Geochemical Indicators of Marine and Fresh-Water Sediments, by M. L. Keith and E. T. Degens
Geochemical Prospecting, by H. E. Hawkes
Geochemistry of Organic Substances, by P. H. Abelson
Some Chemical Aspects of Petroleum Genesis, by W. E. Hanson
Mineral Assemblages of the Green River Formation, by Charles Milton and H. P. Eugster
Tritium in Hydrology and Meteorology, by W. F. Libby
Measurement and Use of Natural Radiocarbon, by Hessel de Vries
Geochronology, by G. R. Tilton and G. L. Davis
The Variations of the O^{18}/O^{16} Ratio in Nature and Some Geologic Implications, by Samuel Epstein
Isotopic Fractionation of Sulfur in Geochemical Processes, by W. U. Ault
The Use of Equilibrium Calculations in Finding the

Composition of a Magmatic Gas Phase, by K. B. Krauskopf
The Chemical Environment of Ore Deposition and the Problem of Low-Temperature Ore Transport, by P. B. Barton, Jr.
Sulfide Systems as Geological Thermometers, by Gunnar Kullerud
Some Aspects of the Geochemistry of Carbonates, by J. R. Goldsmith
Diffraction Effects of Short-Range Ordering in Layered Sequences, by Felix Chayes
Hydrothermal Investigations of Amphiboles, by F. R. Boyd
Reduction and Oxidation in Metamorphism, by H. P. Eugster
Local Equilibrium in Metasomatic Processes, by J. B. Thompson, Jr.
Activation Analysis Applied to Geochemical Problems, by G. W. Reed
Chondrites and the Chemical Composition of the Earth, by G. J. F. MacDonald
Equations of State and Polymorphism at High Pressures, by S. P. Clark, Jr.

Irrespective of the specialty of the Earth scientists, there is something here for all. It is not a 'refresher' type of book but is provocative and stimulating in its treatment of the subject.

The proceeds from the royalties of this book have been conveyed by the editor and authors to the Geochemical Society as a fund for future publications by the Society.

George T. Faust

List of Recent Books of Interest and Importance to Geophysicists

CHAPMAN, V. J., *Salt Marshes and Salt Deserts of the World*, Interscience, New York, xvi + 392 pp., 1960, $14.50.

COWEN, ROBERT C., *Frontiers of the Sea: the Story of Oceanographic Exploration*, Doubleday, New York, 307 pp., 1960, $4.95.

DE VRIES, LOUIS, *German-English Science Dictionary for the Students in Chemistry, Physics, Biology, Agriculture, and Related Sciences*, McGraw-Hill, 3rd ed., 592 pp., 1959, $7.00.

DRAPER, C. S., W. WRIGLEY, AND J. HOBORKA, *Inertial Guidance*, International Series on Aeronautical Sciences and Space Flight (Vol. 3), Pergamon Press, New York, 190 pp., Sept. 1960, $6.50.

DWYER, L. J., (ED.), *Antarctic Meteorology*, Commonwealth Bureau of Meteorology, Melbourne, Australia, 410 pp., 1960, $17.50.

ECKART, CARL, *Hydrodynamics of Oceans and Atmospheres*, Pergamon Press, 304 pp., 1960, $9.00.

EMORY, K. O., *The Sea off Southern California: A Habitat of Petroleum*, John Wiley and Sons, 366 pp., 1960, $12.50.

FEIGELSON, E. M., AND OTHERS, *Calculation of the Brightness of Light in the Case of Anisotropic Scattering*, Consultants Bureau, New York, 104 pp., 1960. (Translated from the Russian; Transactions of the Institute of Atmospheric Physics, no. 1, 1958).

GARRELLS, R. M., *Mineral Equilibria at Low Temperature and Pressure*, Harper and Brothers, New York, 254 pp., 1960, $6.00.

GEORGE, JOSEPH J., *Weather Forecasting for Aeronautics*, Academic Press, New York, 682 pp., 1960, $15.00.

HESS, H. H., *Stillwater Igneous Complex, Montana*, Memoir 80, Geological Society of America, New York, 230 pp., 1960.

HOCKENSMITH, ROY D. (ED.), *Water and Agriculture*, AAAS Symposium no. 62, Am. Assoc. for the Advancement of Science, Washington, 206 pp., $5.00, 1960.

JACOBS, J. A., R. D. RUSSELL, AND J. TUZO WILSON, *Physics and Geology*, McGraw-Hill, 424 pp., 1960, $9.75.

JASTROW, ROBERT, (ED.), *The Exploration of Space*, Macmillan, New York, 160 pp., 1960, $5.50. (Contains papers presented as a symposium in 1959).

JONES, W. R., J. W. PEOPLES, AND A. L. HOWLAND, *Igneous and Tectonic Structures of the Stillwater Complex Montana*, U. S. Geol. Surv. Bull. 1071-H. Gov't Printing Office, Washington, 59 pp., 1960, $1.00.

KAZINSKII, V. A., *Mathematical Tables for the Approximations of Geophysical Anomalies and Reductions by Interpolation*, Pergamon Press, New York, 100 pp., 1960, $5.50.

KRAUSKOPF, KONRAD, AND ARTHUR BEISER, *The Physical Universe*, McGraw-Hill, New York, 544 pp., 1960, $8.95.

KUIPER, G. P., (ED.), *Photographic Lunar Atlas*, Univ. of Chicago Press, 1960, $25 (Based on photographs taken at the Mount Wilson, Pic du Midi, McDonald, and Yerkes Observatories).

LACHMANN, G. V., (ED.), *Boundary Layer and Flow Control—Principles and Applications*, Pergamon Press, New York, 2 vols., 1170 pp., 1960, $30.00 (set). (Part of International Series on Acronautical Sciences and Space Flight).

LEOPOLD, L. B., AND W. B. LANGBEIN, *A Primer on Water*, Supt. of Documents, Gov't Printing Office, Washington, 50 pp., 1960, $0.35.

MCGILL UNIVERSITY: ARCTIC METEOROLOGY RESEARCH GROUP, *Publications in Meteorology, no. 18*, Quartermaster Research and Engineering Command, Natick, Mass., 206 pp., 1960.

MENZEL, DONALD H., (ED.), *The Radio Noise Spectrum*, Harvard Univ. Press, 191 pp., $7.50, 1960.

NEWELL, HOMER E. JR., *Window in the Sky*, The story of our upper atmosphere, McGraw-Hill, New York, 116 pp., 1960, $2.75.

NIKITIN, N. (ED.), *Marine Biology*, Transactions of the Institute of Oceanography, vol. 20, USSR, Academy of Sciences Press, Moscow, 1957; American Institute of Biological Sciences, Washington, D. C., 302 pp., 1960; AIBS members and non-profit libraries $7.50, others $10.00.

ORDWAY, FREDERICK I., III (ED.), *Advances in Space Science*, vol. 2, Academic Press, New York, 463 pp., 1960, $13.00.

ORDWAY, FREDERIC I., III, and RONALD C. WAKEFORD, *International Missile and Spacecraft Guide*, McGraw-Hill, New York, 411 pp., July, 1960, $25.00.

RAINWATER, R. H., AND L. L. THATCHER, *Methods of Collection and Analysis of Water Samples*, U. S. Geol. Survey, W. S. Paper 1454, Supt. of Documents, Washington, 301 pp., 1960, $1.50.

RATCLIFFE, J. A. (ED.), *Physics of the Upper Atmosphere*, Academic Press, New York, 598 pp., 1960, $14.50.

RICHARDS, HORACE G., *The Story of Earth Science*, J. B. Lippincott Co., Philadelphia, 169 pp., 1959, $3.75.

RUNCORN, S. K., (ED.), *Methods and Techniques in Geophysics*, Vol. 1, Interscience Publishers, New York, 387 pp., 1960, $10.00.

SCHNEER, CECIL J., *The Search for Order*, Harper, New York, 415 pp., 1960, $6.00.

SMALE, A. A., AND L. R. WAGER, (Eds), *Methods in Geochemistry*, Interscience, New York, 471 pp., 1960, $13.60.

SMITHSONIAN INSTITUTION, *Smithsonian Contributions to Astrophysics*: vol. 3, no. 9, 70 pp.; *Geodetic Uses of Artificial Satellites*, 70 pp.; vol. 4, no. 1, *Catalog of Hourly Meteor Rates*, 14 pp., Smithsonian Institution, Washington 25, D. C., 1960.

U. S. AIR FORCE, *Handbook of Geophysics*, Macmillan, revised edition, 680 pp., 1960, $15.00 (Reference work of recent data from satellite and rocket observations, solar observatory, Arctic expeditions, aircraft and balloon flights, and laboratory experiments.)

U. S. DEPT. OF COMMERCE, WEATHER BUREAU—U. S. DEPT. OF THE NAVY, HYDROGRAPHIC OFFICE, *Climatological and Oceanographic Atlas for Mariners, Vol. 1, North Atlantic Ocean*, Government Printing Office, Washington, v + 6 pp., 182 charts, 1959, $2.25.

Contents of Bulletin (Izvestia), Academy of Sciences, U.S.S.R. Geophysics Series, January—March 1960

Note—Starting with the March 1959 issue of the *Transactions*, the contents of *Izvestiya*, Geophysics Series, for 1957–1960, are to be found in successive issues.

The production of the English edition has been undertaken with the aid of a grant from the National Science Foundation starting with the series for 1957. Orders for sets for 1957, 1958, 1959, and 1960 ($25.00 for each set of twelve numbers) should be sent to the American Geophysical Union. Individual numbers are available for $5.00 each. Subscriptions are now being received for the 1960 series at a price of $25.00 for the year.

No. 1, January 1960

Convection in the Earth's mantle, E. N. Lustig, 4 pp.

The frequency theory of interference systems. I, F. M. Holzmann, 17 pp.

Dynamic peculiarities of multiple reflected 'water' waves in the ocean and their use in the determination of elastic waves in sediments, S. M. Sverev, 13 pp.

Origin of the reversed magnetization of volcanic rocks from Armenia and the Kuril Islands, G. A. Pospelova, 13 pp.

On short-period variations of the regional electromagnetic field, A. G. Kalashnikov and E. N. Mokhova, 5 pp.

A study of the triboelectric effect in rocks and in certain dielectrics by means of a dynamic method, E. I. Parkhomenko, 8 pp.

Study of the propagation of elastic waves of ultrasonic frequency over small distances in rocks, under conditions of natural deposition, V. I. Myachkin and R. N. Solov'eva, 11 pp.

The quasistationary property of drift currents in the ocean, V. M. Kamenkovich, 9 pp.

The determination of the dependence on height of the turbulence coefficient in the lower layer of the atmosphere, L. T. Matveev, 6 pp.

Investigation of electrification processes of cloud particles and of precipitation, N. V. Krasnogorskaya, 9 pp.

Some results of measurements of air temperature by a local acoustic method up to an altitude of 28 km, M. I. Mordukhovich, 9 pp.

The results of a complex investigation of the type St—Sc clouds and fogs in the Arctic, A. L. Dergach, G. M. Zabrodsky, and V. G. Morachevsky, 8 pp.

Certain results of model investigations according to the inductive method, B. S. Svetov, 11 pp.

Converted and reflected waves on azimuthal seismograms of earthquakes in the Garm region, E. V. Glivenko, 5 pp.

Some special features in the structure of the Earth's crust in Central Asia according to records of high-power explosions, V. I. Ulomov, 4 pp.

On the evaluation of the intensity of earthquakes in

the territory of China, E. F. Savarensky and Mei Shi-yun, 4 pp.
The feasibility of using the Earth's natural electromagnetic field for geological surveying, N. P. Vladimirov, 3 pp.
An apparatus for measuring small remanent magnetisation of rocks, V. I. Dianov-Klokov, 6 pp.
On the diurnal variation of Earth current disturbances as observed by Soviet stations during the IGY, V. M. Mishin and O. M. Barsukov, 3 pp.
The dependence of the damping of impulses in layers of finite thickness on the frequency spectra, O. G. Shamina, 4 pp.
On the three 'velocities' of corpuscular streams, O. M. Barsukov, 3 pp.
The influence of the character of a lava flow on the formation of remanent magnetization of rocks, G. I. Kruglyakova and V. V. Kruglyakov, 3 pp.
On the certain zonal peculiarities of the general circulation of the atmosphere, G. V. Gruza, 4 pp.
A turbulent regime above the ground atmospheric layer, A. B. Kazanski and A. S. Monin, 4 pp.
On the kinematics of local winds of the Alazan Valley, S. V. Borissova and E. A. Burman, 5 pp.
Diffusion of an admixture in a field of homogeneous isotropic turbulence, R. V. Ozmidov, 2 pp.
Chronicle: Seminar on seismic regional divisions of the Carpathians, 1 p.

No. 2, February 1960

New principles in establishing seismic regions, based on an example from Central Tien-Shan. I, M. V. Gzovsky, V. N. Krestnikov, I. L. Nersessov, and G. I. Reisner, 22 pp.
Azimuth-phase correlation of elliptically polarized seismic waves, E. I. Gal'perin and A. V. Frolova, 14 pp.
The frequency theory of interference systems. II, F. M. Holzmann, 14 pp.
On the application of seismic frequency sounding for the investigation of the upper part of a cross-section, T. G. Ivanova, 6 pp.
Automatic equipment at the seismic stations of the North-Tien-Shan zone, A. A. Vogel, 7 pp.
IGY observations of the vector of horizontal geomagnetic field variations, A. G. Kalashnikov and K. Yu. Zybin, 7 pp.
Thermal history of the Earth, B. Yu. Levin and S. V. Maeva, 10 pp.
Optimum conditions for continuous activation logging, Yu. P. Bulashevich and S. A. Shulyat'ev, 10 pp.
On the theory for interpreting gamma-ray logs in layered media, G. M. Voskoboinikov, 8 pp.
Density and gravitational effect of paleozoic rocks in the Tatar Republic, A. G. Salikhov and V. P. Stepanov, 8 pp.
Seasonal variations in ocean currents, K. N. Fedorov, 10 pp.
Approximation method of taking into account the horizontal variations in albedo of the underlying surface in problems concerning diffusion of light in the atmosphere, M. S. Malkevich, 11 pp.
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Contents of Geodesy and Cartography, U.S.S.R., January and February 1959

Note—Starting with this issue of the *Transactions*, the contents of the English translation of *Geodesy and Cartography* will appear in successive issues.

Publication of an English edition of this leading monthly journal of Geodesy and Cartography in the USSR has been undertaken with the aid of a grant from the National Science Foundation, starting with Number 1 (January) of the 1959 volume. A volume set of 12 numbers is priced at $20.00, and orders should be sent to the American Geophysical Union. Individual numbers are available for $5.00 each. Subscriptions are now being received for the 1959 volume.

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Many more translations of Russian scientific writings are available than is generally realized. In order to indicate what is available, the Office of Technical Services of the U. S. Department of Commerce has begun a semi-monthly publication entitled *Technical Translations* which lists translations, not only from the Russian but from other languages as well, available through various organizations in the United States, Canada, Great Britain, and Australia. Some of these are translations in full; others are abstracts of papers in journals, as indicated below. The following information bears on subjects that are likely to be of special interest to geophysicists.

The initials indicate sources, as follows: AGI, American Geological Institute, Washington 25, D. C.; ATS, Associated Technical Services, Inc., P. O. Box 271, East Orange, New Jersey; CB, Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York; DRB, Defense Research Board, Directorate of Scientific Information, "A" Building, Cartier Square, Ottawa, Ontario, Canada; HIG, Hawaii Institute of Geophysics, University of Hawaii, Honolulu 14, Hawaii; LC, Photoduplication Service, Library of Congress, Washington 25, D. C.; MDF, Morris D. Friedman, Inc., Foreign Technical Translations, 67 Reservoir Street, Needham Heights 94, Massachusetts; ATS, Office of Technical Services, Department of Commerce, Washington 25, D. C.; PP, Pergamon Press, 122 East 55th St., New York 22, N. Y.; RR, Royer and Roger, Inc., International Division, Washington, D. C.; SLA, SLA Translation Center, The John Crerar Library, 86 Randolph Street, Chicago 1, Illinois; mi, microfilm; ph, photostat.

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Notes and Personalia

Notes

• CORRIGENDUM—In the June 1960 issue of Transactions three minor errors appear in the article 'Auroral Spectroscopy' (Oliver). On page 237, first column, line 5, read "on the 0I5577 line and in afterglows"; same page and column, line 20 should read H_α, *not* H_β. On page 238, second column, line 14, read 'University of Southern California'.

• UNDERWATER SOUND WAVES RECORDED THROUGH 12,000 MILES—Sound waves generated by depth charges fired by the Lamont Geological Laboratory's research vessel *Vema* at a point off the coast of Australia, were picked up at the Laboratory's Bermuda Station. This indicates a travel of 12,000 miles for recorded waves, or nearly halfway around the Earth. This is almost the maximum distance for such reception, inasmuch as the circumference of the Earth is less than 25,000. The travel time was reported to be approximately 144 minutes. The sound waves followed a great circle past the Cape of Good Hope, dropping to depths of about 4200 feet near the Equator; such waves could be picked up only in areas where a great circle path traverses deep water. The instruments at the Bermuda Station are at a depth of 4200 feet. Scientists believe that an underwater atomic blast fired near the sound channel could be picked up by the Station.

The principle of SOFAR (Sound Fixing and Ranging), demonstrated by Maurice Ewing, Director of Lamont Observatory, during World War II, has been considered by many to be the most important discovery in communications since radar. For instance, aircraft or ships in distress at sea might be able to signal their position by means of small depth charges. The method was perfected by Ewing in 1945, when sound had been transmitted from Dakar, West Africa, to Bermuda—a distance of 3000 miles—in 62 minutes. The recent recording of shots for a distance of 12,000 miles is considered particularly remarkable because there is no clear, direct path in the water between the firing and reception points. John I. Ewing, also a member of the Observatory staff, pointed out that the sound waves had to follow paths around islands and through shallow areas.

• COESITE DISCOVERED IN FAMOUS BAVARIAN CRATER—Coesite, the dense and highly stable form of silica not known to occur naturally on Earth before it was recently collected and identified by U. S. Geological Survey scientists at Meteor Crater, Arizona, has now been recognized in rock specimens collected near the rim of Germany's famous Rieskessel in Bavaria, the Department of the Interior announced recently. The original find in Arizona was considered by Eugene M. Shoemaker, Survey geologist, to be conclusive evidence that the crater was the result of a collision between the Earth and a sizeable meteorite.

En route to Copenhagen, Shoemaker visited the Ries and its renowned 'Kessel' or crater. While there he was struck by the similarity in appearance between specimens of glass and 'shocked granite' he collected from what has been called 'Suvite', and the 'sheared sandstone' of Arizona in which coesite was first found. Samples were sent back to Washington and examined in the Geological Survey's geochemical laboratories by mineralogist-geologist Edward Chao. Dr. Chao again made X-ray studies similar to those of a few weeks ago on specimens from Arizona, (announced June 17) and was able to report that these new specimens from Germany also contain coesite. A brief announcement of this find was made by Shoemaker in the course of his discussion before the International Congress at Copenhagen.

This means there are now two places known on Earth where coesite occurs in nature. It strengthens the contention of certain German geologists, notably E. Werner, and Otto Stutzer who held to the hypothesis that the Rieskessel was an impact crater. The Ries has been the object of considerable attention and speculation by German scientists for more than 100 years. W. Kranz devoted much of his geological career to its study. W. Branca, Wilhelm Ahrens, Alfred Theodor Bentz and many others wrote extensively on it. Very little of their work has been translated into English.

Unlike Meteor Crater, Arizona, the 'Ries' dates back to the Miocene epoch, of some 12–25 million years ago. This makes it the first such crater to be identified in the Prepleistocene record. One of the strongest arguments against acceptance of a meteoritic origin for the Ries crater has been the complete absence of any concrete evidence of a meteorite having struck the Earth before the Age of Man. There is no doubt about its antiquity, for rubble on the floor of the Ries Plain is overlain by lake sediments definitely identified as late Miocene.

William E. Pecora, chief of the Geological Survey's Geochemistry and Petrology Branch, remarked "we hope that geologists the world over are stimulated to look for coesite and thus increase our knowledge of impact craters on this planet."

• OVERSNOW TRAVERSE PROGRAM IN ANTARCTICA—A grant of nearly one half million dollars, made by National Science Foundation to the University of Wisconsin, will place full responsibility for administering the Federal Government's Oversnow Traverse program in Antarctica in the hands of geophysicists of the University, for approximately two years. This is in continuation of the project carried on during the International Geophysical Year, in which Wisconsin geophysicists, working under the direction of George P. Woollard, played an important part. During IGY the program was administered by the Arctic Institute of North America.

Two ground parties and one air-borne team,

each including two geophysicists, two glaciologists, and a surveyor, will include men from the Univ. of Wisconsin and other institutions. The work will include measurement of ice thicknesses by seismic methods and gravity measurements, study of the crustal structure, mapping of the magnetic field, geologic studies of rock formations, and physiographic features, glaciological studies relating to properties of snow and ice, measurements of annual snowfall, synoptic studies of weather, observations on plant and animal life, and geographic mapping of traverse areas. Geographic data will be sent to the Navy Hydrographic Office, and the American Geographical Society.

Since late 1955 a Data Reduction Center has been maintained at the University, to relate and interpret data obtained on the Oversnow Traverse program during IGY.

● NATIONAL SCIENCE FOUNDATION ANNOUNCES NEW PROGRAM OF INSTITUTIONAL GRANTS—An experimental program of institutional grants made by the National Science Foundation will strengthen the scientific capability of colleges and universities. It complements the Foundation's support of Science and Science Education that is now provided through fellowships and research funds directed toward specific projects. The newly established grants are designed for unspecified use, so as to provide institutions with flexible funds for strengthening and balancing scientific research activities, when additional resources are needed for basic apparatus, services, or publications not provided for under earmarked Federal funds. Amounts of grants under the new program will be limited to five per cent of Foundation research grant payments made to an institution during the preceding year, and may not exceed $50,000 for any fiscal year.

During the current fiscal year the grants will be based on a 9-month period ending March 31, 1961; thereafter they will be based on a 12-month period beginning April 1. Institutions will be required to make annual reports to the Foundation on the use of these funds.

The program will be under the direction of a new Office of Institutional Programs, headed by Louis Levin. This office will also handle the separate NSF program of grants designated specifically for modernization and expansion of research laboratories in U. S. universities.

● INTERNATIONAL COMMISSION ON OCEANOGRAPHY RECOMMENDED—An International Conference on Oceanography, held in Copenhagen, Denmark, July 11-16, preceding the International Geologic Congress, focussed attention on the needs and values of oceanic research and surveys, concentrating particularly on international cooperation in oceanography, and the promotion of research on the international as well as national level. Items on the agenda included: status of knowledge and research, procedures for acquiring data, standardization of methods, exchange of data, training programs, joint operation of international research, and related subjects.

It was recognized that one of the main obstacles to oceanographic research is the lack of qualified oceanographers, and it was recommended that the number of fellowships financed by UNESCO be increased appreciably. The Conference recommended also standardization and intercalibration of methods and equipment, and that UNESCO set up a permanent intergovernmental oceanographic commission to coordinate research; the IOC would work with a special Office of Oceanography set up within the UNESCO Department of Natural Sciences. Roger Revelle, Director of the Scripps Institution of Oceanography, and member of the U. S. National Commission for UNESCO, was a member of the delegation.

● PERU CURRENT SYSTEM UNDER SPECIAL STUDY—The Research Vessel *Horizon* left San Diego, California, on September 15 for a three-month expedition, known as STEP-I, to study the Peru Current System. Warren S. Wooster, Associate Research Oceanographer of Scripp's Institution of Oceanography of the University of California is in charge of the expedition, which is sponsored by the National Science Foundation, the Inter-American Tropical Tuna Commission, the U. S. Bureau of Commercial Fisheries, and the Office of Naval Research.

Studies of the System, based on existing oceanographic data and theory, have indicated the need for further measurements regarding (1) the nature of the north boundary and the velocity field in the transitions zone—physically, chemically and biologically; (2) the density distribution near coasts where a subsurface counter-current may be indicated; (3) the possibility of a separation of the System from the eastern boundary current off Chile; (4) data on carbon fixation and high organic productivity; (5) oceanographic data of the western portion of the System; and (6) the nature of the deep circulation, as inferred from the distribution of properties on deep stations.

Water samples will also be collected for Dr. Roland Cox of the National Institute of Oceanography, England, who is carrying out a World-wide analysis of the relationship between chlorinity, salinity, conductivity, density, and refractive index.

It is anticipated that the investigation will be coordinated with work by the Peruvian Consejo de Investigaciones Hidrobiologicas, and that several Peruvian scientists will participate.

● WORLD METEOROLOGICAL ORGANIZATION HAS PROGRESSIVE PROGRAM—The development and use of artificial satellites for providing weather data is one of the objectives in the program of the World Meteorological Organization, according to UNESCO. A panel of experts set up by WMO recommended that methods should be proposed for providing information about clouds, and for sending out storm warnings based on satellite observations.

Also noted in the report submitted to the United Nations is the world-wide study on tidal waves and warning systems; a symposium on this subject is being planned by the International Union of Geodesy and Geophysics.

This year WMO is celebrating its tenth anniversary as an agency of the United Nations; however, its international collaboration in meteorology dates back to 1878, when the International Meteorological Organization was set up as a non-governmental body. Membership now includes practically every country. One of its most important tasks during the ten years of its existence as a governmental organization and specialized agency of the United Nations has been the development of the meteorological program of the IGY, and the collection and distribution of data to researchers of all countries.

● RESEARCH VESSEL *Vema* RETURNS FROM YEAR-LONG VOYAGE—Columbia University's R. V. *Vema* has returned to home port after a highly profitable voyage that began October 1, 1959. One of the major projects was examination of the Mid-Ocean Ridge, a 45,000-mile crack in the Earth's crust beneath the major oceans. It was discovered that the crack in the floor of the Atlantic Ocean joins a break in the floor of the Indian Ocean just south of the tip of Africa. Precision recordings showed that the top of the valley ranges from one to nearly two miles below the surface of the ocean, and the bottom from two to three miles below the surface; the width of the crack is one to five miles at the bottom, and four to 20 miles at the top.

Another discovery was a submarine canyon in the South Atlantic off the coast of Argentina; the canyon is five to 12 miles wide at the top, nearly a mile wide at the bottom, and several hundred miles long, and so is much larger than the Grand Canyon. It is believed to have been carved by moving loads of sediment from an 'Ice Age' river that once flowed through Argentina.

New evidence was obtained also that tremendous landslides, or 'turbidity currents,' occur periodically beneath the ocean.

● ANTARCTIC RESEARCH PROGRAM FOR 1961—The National Science Foundation has announced that 45 grants and one contract, totalling $3,175,096, have been awarded to carry on scientific research in the Antarctic during fiscal 1961, beginning in October. The NFS administers the United States Antarctic Research, and Antarctic Research money is awarded to several government agencies as well as many educational and scientific institutions. Additional grants are expected to bring the 1961 support to approximately $4 million.

Research in the Antarctic under this program, includes the fields of aurorae, biology, cosmic rays, geodesy and cartography, geology, geomagnetism, geophysics, glaciology, ionospheric physics, meteorology, oceanography, and seismology. The field program is made possible through the logistic support of the Department of the Navy, which was responsible also for the supply operations of the IGY Antarctic projects.

The NSF will support also, this year, a research project in the adjoining, little-known Amundsen Sea area, and embracing the fields of biology, geology, cartography, oceanography, glaciology, and meteorology.

● NEW OCEANIC ATLAS FOR ATLANTIC AVAILABLE—The Woods Hole Oceanographic Institution has launched a new series of oceanic atlases with publication of the first volume of *The Atlantic Ocean Atlas of Temperature and Salinity*. The Atlas was prepared by F. C. Fuglister and associates as part of the Institution's contribution to the IGY. Forty-six colored charts or profiles that show the salinities and temperatures of the North and South Atlantic Oceans from the surface to the bottom, eight profiles in color that give more detailed data on temperatures for the top 500 feet of water at different latitudes across the ocean, and all the data from which the profiles were drawn are included in the 210 pages of the Atlas, which measures 12 x 17 inches. The volume is printed on special paper made for durability at sea, so that it is designed as both a reference work and a working tool for oceanographers and other specialists who work at sea.

The new Atlas is the most complete collection of such data since the publication of the results of the expedition of the German ship *Meteor* in 1925–27, which, however, concentrated only on the South Atlantic.

The observations for the new Atlas were made between September 1954 and July 1959, from research vessels *Crawford*, *Atlantis*, and *Chain*, of the Woods Hole Oceanographic Institution, and *Discovery II* of the National Institute of Oceanography, of England. The work was supported by the National Science Foundation and the Office of Naval Research, and publication of the Atlas was financed by NSF in support of its IGY Interdisciplinary Research Program. Copies of the Atlas are obtainable from the Woods Hole Oceanographic Institution.

● FOREIGN SCIENTIFIC PUBLICATION TRANSLATED ABROAD—The first delivery of Russian Scientific and Technical publications translated abroad under a cooperative Federal agency program has been announced by the NSF and the Dept. of Commerce. The translations were prepared under a contract with the Israel Program for Scientific Translations. Projects are now under way in Israel, Poland, and Yugoslavia to produce translations of 89,000 pages of material published originally in languages unfamiliar to most U. S. scientists.

Besides the Israeli program for translation of approximately 50,000 pages of Russian material, a contract with the Central Institute for Scientific and Technical Documentation, at Warsaw, provides for translation of 19,000 pages of Polish literature. Another contract with the Yugoslav Directorate for Scientific Research provides for translation of approximately 20,000 pages of Serbo-Croatian literature; it is planned to include other East European languages later. The NSF assists participating Government agencies in the selection of material to be translated; final selection is made by Government scientists on the basis of the needs of their agencies and the requirements of the scientific community.

The Office of Technical Services, U. S. Dept.

of Commerce receives, catalogs, distributes, and sells the translations at approximately one cent per page. New translations are announced in *Technical Translations*, published twice monthly, and available through the Supt. of Documents, Washington.

• REPORTS ON HURRICANE DONNA SAVED MANY LIVES—The tracking, warning, and forecasts for hurricane Donna were the most complete in history, saved hundreds of lives, and prevented thousands of injuries, according to F. W. Reichelderfer, Chief of the U. S. Weather Bureau. Donna was doubtless the most destructive and vicious tropical storm since Bureau records were started, in 1886.

After the 1954 and 1955 hurricane seasons, the Dept. of Commerce proposed measures for hurricane research and observational operations that received financial support from Congress sufficient to promote and expand the hurricane warning system. Installation of high-powered radar in 1959 and 1960 paid real dividends during Donna's passage, so that, owing to warnings and advisories, 95 per cent of the people in the Florida Keys could be evacuated from vulnerable areas in time, and adequate measures could also be taken in other critical areas from Florida to Maine. Effective coordination of activities and emergency measures was carried out with the Navy and Air Force hurricane hunters, and with the OCDM, Red Cross, and state and local authorities who are also tied into the Bureau's warning system.

• CENTER FOR ATMOSPHERIC RESEARCH TO BE ESTABLISHED—The National Science Foundation has allotted $50,000 under contract with the University Corporation on Atmospheric Research to assist in establishing a national center on atmospheric research. The center will be staffed by a group of eight or more scientists under the direction of Walter Orr Roberts, Director of the High Altitude Observatory, Boulder, Colorado. The principal functions of the group are to stimulate and supplement university research, and to provide coordination of projects.

Most of the research will probably remain with university groups, so that the center may operate at several localities, though a headquarters will be established. Research programs are expected to be in four fields, namely, (1) atmospheric motions, (2) energy exchange processes, (3) water substance in the atmosphere, and (4) physical phenomena in the atmosphere. The staff will probably include meteorologists, physicists, chemists, and engineers.

• FINANCIAL ASSISTANCE FOR GRADUATE STUDENTS IN METEOROLOGY AT THE UNIVERSITY OF CHICAGO—The Department of Meteorology of the University of Chicago will provide several kinds of financial assistance for qualified students in meteorology for the academic year 1961–62. Three Graduate Fellowships in the Atmospheric Sciences provide annual stipends of $3000, plus $1290 for tuition and fees; these fellowships are available not only to students already in the field of meteorology, but also to others who have backgrounds in the physical sciences, but have not previously studied meteorology. Teaching fellowships, with stipends of $800 per quarter plus tuition costs, are available for students with promising academic records. The LaVerne Noyes Foundation Scholarship provides tuition for students who are descendants of World War I veterans. Research assistantships (half-time) with stipends of $2250 and up for the nine-month academic year, and with opportunity for summer employment, are also available. Applications for fellowships and scholarships must be received on or before February 15, 1961. Application forms may be obtained by writing to Counselor, Department of Meteorology, University of Chicago, Chicago 37, Illinois.

• NEW TOOLS FOR TEACHING SCIENCE—With the aid of grants from the National Science Foundation totalling $284,450, scientists and engineers will design new tools for the teaching of Science, Mathematics, and Engineering. The teaching aids will include an educational wind tunnel (using smoke to visualize air flow), a small hypersonic wind tunnel, inexpensive computers, a mass spectrophotometer, a model X ray circuit, and equipment for instructional methods of mechanical analysis. The apparatus will be used to help competent scientists develop new equipment of wide usefulness. Information regarding the development and availability will be disseminated to teachers throughout the country by means of articles in journals and reports at meetings. In announcing the awards, Alan T. Waterman, Director of NSF said, "The equipment devised by the grantees will help bring the phenomena and ideas with which contemporary science is concerned into the classroom."

• GEOLOGICAL SURVEY MAKES MOON SURFACE STUDY FOR ARMY ENGINEERS—A terrain study of the Moon, to provide lunar surface information for selecting landing sites, and as an aid in designing telemetering instruments and a lunar surface vehicle, has been completed for the U. S. Army Corps of Engineers, by the Military Geology Branch of the U. S. Geological Survey. The study consists of three diagrams of the visible face of the Moon; one diagram shows the physiographic regions, the second diagram is a generalized photogeologic map, showing fracture patterns, faults, anticlines, monoclines, and other structural features, and the third indicates the prominent lunar rays, believed to be 'splashes' of crushed rock derived from the impact of large fragments thrown out at times of meteoric impact. The accompanying brief text describes the physiographic regions, and provides information on relief and slopes. Interpretations are made of the probable composition and texture of the surface material, and its bearing strength.

• DISPOSAL OF RADIOACTIVE WASTES AT SEA—The International Atomic Energy Agency has just published the first volume of its Proceedings on the Monaco Conference of November 1959. This meeting brought together nearly 300 of the World's leading oceanographers, physicists, nuclear engineers, and biologists to consider the desirability of

disposing of radioactive wastes at sea. The 603-page report on the conference is available from IAEA, room 2249, United Nations B'ld'g, New York City; price, $6.00.

The IAEA, an autonomous agency affiliated with the United Nations, and made up of representatives of 70 nations, was established in July, 1957, 'to foster the exchange of scientific information on peaceful uses of atomic energy'. Other functions involve various aspects of atomic research, training and technical assistance for the less developed nations, preparation of international agreements on health and safety, and related matters. As a result of these important activities it has become prominent in the publishing of technical reports and books relating to problems in the field of atomic energy.

● COLUMBIA UNIVERSITY EXPANDS IN FIELD OF METEOROLOGY—Research activities and graduate training leading to advanced degrees in meteorology have been inaugurated at Columbia University, according to an announcement made by Maurice Ewing, Director of the University's Lamont Geological Observatory. In support of its new research program in dynamical meteorology the University has received grants of $173,440; the largest grant—$133,400—was given by National Science Foundation, which is supporting the program's theoretical studies over a three-year period. Diagnostic studies of weather developments are supported by an award of $30,000 from the Office of Naval Research.

Other meteorological research programs besides those in dynamical meteorology include studies in atmospheric micro-oscillations (supported by NSF), in waves and sea-level observations at island observatories (supported by ONR), and in climatic change (supported by the U. S. Steel Foundation).

The graduate training program is integrated closely with the various research activities. Student candidates for M.A. and Ph.D. degrees in meteorology need not have had prior training in this field; they must, however, meet requirements of the Department of Geology relating to the Cognate Fields Program, and hold a bachelor's degree with a major in science, mathematics, or engineering from an accredited college. Opportunities for financial support include research assistantships, fellowships, and scholarships.

● NEW SEISMOGRAPH STATIONS TO BE ESTABLISHED BY ST. LOUIS UNIVERSITY—Four new seismograph stations will be established by St. Louis University, to be located in Kansas, Ohio, Iowa, and Missouri, for the purpose of studying earthquakes and the characteristics of waves traveling in the Earth, under contracts awarded by the Advanced Research Projects Agency of the Department of Defense. The work is part of Project Vela Uniform.

The contracts—totalling nearly $250,000—were awarded by the Air Force Research Division and are an outgrowth of a study of the Panel on Seismic Improvement, headed by Lloyd V. Berkner, President of AGU, and made up of leading American scientists. The study called for more basic research in the field of seismology.

It is expected that the results may eventually help to distinguish between earthquakes and underground nuclear explosions.

● UNIV. OF WISCONSIN RECEIVES GRANTS FOR GEOPHYSICAL AND GEOLOGIC RESEARCH—Two large research grants have been received by the Department of Geology of the University of Wisconsin. The largest is for $125,490, from the National Science Foundation, for establishing a Polar and Geophysical Research Center. Some of the research activities to benefit by this grant are: an Antarctic program of airborne and ground traverses for geophysical, geological, and glaciological studies; a data reduction program for IGY studies in Antarctica; seismic studies of the Earth's crust; and gravity studies of the United States.

The second grant consisting of $45,000 from the National Academy of Sciences, will support studies of the Earth's gravity that UW researchers began during the IGY.

● ELECTRIC ANALOG MODELS SIMULATE GROUND WATER SYSTEMS—Engineers and scientists of the Department of the Interior's Geological Survey have put together an ingenious electronic device, known as the 'Analog Model Analyzer', that is capable of predicting the effects of long-term pumping from an underground reservoir, or aquifer, of describing water movement through Earth materials, and also, of determining how long a given local water supply will last as more and more users move into a community.

The 'Analyzer' consists of two units: one, a network of electric resistors and capacitors built into a scale model of a given aquifer as visualized by geologists; the other, an electric pulse generator which stimulates the water 'head' changes that occur when a well is pumped, coupled with an oscilloscope that translates head changes into a drawdown graph on a fluorescent screen.

Engineers have been able to describe and interpret the forces that influence the rates and directions in which ground water moves through various kinds of soil, sand, and rock, but how to accomplish accurate measurements and make such predictions has challenged geologists and engineers for many years. To inventory an underground resource so as to determine how long a given water supply would last in the face of rising demand has involved mathematics that mean almost endless calculation. The most powerful mathematical techniques and the most versatile high-speed commercial computers held no promise for the required solutions of complex hydrologic problems. The well-known idea of applying the near-perfect analogy between the laws describing the flow of electricity and the laws describing the movement of ground water has resulted in development of the model analyzer. Once the local geologic environment is simulated electronically, a rapid analysis of ground-water flow problems can be made.

According to Dr. Luna B. Leopold, Chief Hydraulic Engineer of the Geological Survey,

"Results of these specific uses of model technique have convincingly demonstrated that all the com-

plex field data assembled by geologists and engineers can be put together, analyzed, and subsequently applied to forecast the effects of water-supply developments envisioned by a community anywhere. Ground-water developments have had a topsy-like growth, and, while the total storage is very great, ground-water problems will continue and increase in severity until the developments are planned and operated with greater attention to the specific hydrologic factors of each area."

Today the Survey has a Hydrologic Analog Model Unit established in Phoenix to provide services to its district offices in most of the 50 states. The unit is "open for business" and prepared to apply electric analog model techniques to the solution of complex ground-water-flow problems under study by the Survey.

• NEW GRADUATE SCHOOL FOR SCIENCE AND ENGINEERING ESTABLISHED BY UNIVERSITY OF CALIFORNIA—The Board of Regents of the University of California has added a Graduate School of Science and Engineering at La Jolla campus. Curricula will include Physics, Chemistry, Earth Sciences, and Biological Sciences. The Scripps Institution of Oceanography will continue as a research institute for marine sciences, and several of its faculty will also be members of the faculty of the new Graduate School, which will have a Department of Oceanography, and a branch of the University's Institute of Physics to be headed by Walter Munk.

• METEORITE COLLECTION ACQUIRED BY UNIVERSITY OF ARIZONA—A collection of 1220 catalogued meteorites collected by Dr. Harlow Nininger, and representing nearly half the approximately 1600 known falls, has been acquired by the University of Arizona. This is the fourth largest collection of its kind in the World, and will be housed in the University's new physical sciences building. The meteorites are of particular value in space research, according to Dr. Nininger, for he believes that if Man ever navigates the interstellar regions he must do so in vessels made of minerals similar to those of meteoric origin that have not disintegrated on entering the Earth's atmosphere.

• U. S. FUNDS FOR BASIC RESEARCH REACH A BILLION DOLLARS A YEAR—The National Science Foundation has estimated that total funds for basic research in the United States have reached one billion dollars for 1959–60. This represents an increase of approximately 570 million dollars over the period 1953–54. It amounts to about eight per cent of the total estimated funds for research and development. The Foundation reports that the substantial rise in the level of basic research funds is part of a long-term increase in scientific and technological activity stimulated, in particular, by the challenging proolems of the past two decades.

• NSF AWARDS $2 MILLION TO IMPROVE RESEARCH FACILITIES—Grants to 54 colleges and universities, and totalling $2,153,710, for improvement of graduate research laboratories, have been announced by the National Science Foundation. The awards are made on a matching basis that requires at least 50 per cent of the needed funds to be provided by the institution. The grants provide for construction, conversion, or modernization of laboratory facilities, and are designed to alleviate the obsolescence or inadequacy of research laboratories devoted primarily to graduate studies that are vital to National basic research.

• NEW LAKE LABORATORY FOR UNIVERSITY OF WISCONSIN—A grant of $480,000 from the National Science Foundation will enable the University to build a new lake laboratory, replacing the present quonset hut laboratory that has been far outgrown. Though related chiefly to hydrobiological research, the lake studies also provide an experimental approach to certain problems of oceanography. The new laboratory will be built in about two years.

• BASIC RESEARCH PROVIDED IN DEFENSE DEPT., BILL—The appropriation for the Department of Defense for the fiscal year beginning July 1, 1960, included $136 million for basic research, or approximately a quarter of the total Federal investment for this purpose. This is nearly 3½ per cent of the total appropriation for research, development, test, and evaluation. In making grants and allotments the Defense Department identifies areas to support, and then seeks people in universities and foundations for work in these areas.

• FORD FOUNDATION GRANT TO BROOKLYN POLYTECH PROMOTES ACCELERATED HONORS PROGRAM—The Ford Foundation has awarded $700,000 to the Polytechnic Institute of Brooklyn to establish an 'honors program' in science and engineering. Exceptional students will be able to receive a doctorate in six years of full-time study. Under the new program, no strict dividing line is made between undergraduate and graduate students. After the first two years of a basic curriculum of mathematics, physics, and the humanities honors students will begin specialization in selected areas, and will participate in seminars and special lectures; they will also conduct faculty supervised research projects early in the program. About six per cent of the September class is enrolled in the honors program.

• NEW SCIENCE CENTER AT WESTERN RESERVE UNIVERSITY—A ground breaking ceremony for a $6,270,000 Science Center at Western Reserve University was held on July 14, 1960. The first building, for basic sciences, will be known as the John Schoff Mills Science Center, and will provide laboratories, library, auditorium, and departmental facilities for geology, geography, astronomy, physics, chemistry, mathematics, and biology. The first part of the building is expected to be ready in late 1961, the remainder by spring 1962.

• ENGINEERING SCHOOLS SPENT $71 MILLION IN 1958 FOR SPONSORED RESEARCH—As part of its study of funds spent on research and development, the National Science Foundation reports that [in fiscal 1958, engineering schools of the United States spent $71 million on sponsored ('earmarked') research and development, 57 per cent of which was used for basic research. Of these funds, the schools received $48.6 million from the Federal

Government, and $10.3 million from industries; the remainder came from their own funds.

● SATELLITE OBSERVATORIES PROJECTED AT UNIV. OF WISCONSIN—A project to launch satellite observatories capable of taking very accurate astronomical measurements from high altitudes in space is under way at the University of Wisconsin. A contract with the National Aeronautics and Space Administration gives Federal funds amounting to $105,500, to the University for this purpose. The University is one of five institutions that are participating in NASA's orbiting observatories program; the other four are: Harvard Univ., Princeton Univ., the Smithsonian Institution, and Goddard Space Laboratories (NASA).

● GRANT TO STUDY PHASE RELATIONS IN SULFIDE SYSTEMS—Lehigh University has received a grant of nearly $9000 from the Research Corporation of New York for the study of phase relations in sulfide systems. H. Richard Gault, head of the Department of Geology, is directing the research. The grant includes support for a graduate fellow.

NEW FILMSTRIP FOR TEACHING CLOUD AND WEATHER FACTS—Unesco has issued a color filmstrip, "Clouds and Meteors," to help in teaching cloud classification and weather observations. The 35 photos contained in the film illustrate definitions of clouds and meteors, and the factors that determine the appearances of clouds; they are explained in a text prepared by Dr. W. Bleeker of the Royal Netherlands Meteorological Institute. The filmstrip is a simplified version of a more technical strip for meteorological students, produced by Unesco and the World Meteorological Organization. Further information may be obtained from the Visual Media Division, Dept. of Mass Communication, Unesco, Place de Fontenoy, Paris, France.

● NEW RESEARCH VESSEL COMMISSIONED BY SCRIPPS INSTITUTION OF OCEANOGRAPHY—Commissioning ceremonies for the Research Vessel Argo, newest and largest ship of the Scripps fleet, were held at San Diego on August 13. Rear Admiral Rawson Bennett II, Chief of Naval Research, delivered the principal address.

The 2000-ton Argo is 213 feet long, and was a former auxiliary rescue and salvage vessel; it has been leased to the University of California by the Bureau of Ships. Funds for converting it into an oceanographic research ship were provided by the Office of Naval Research. It is in service in the southwest Pacific and Indian Oceans, as Scripps' first contribution to the four-to-five year cooperative international exploration program.

● IMPROVEMENTS IN HURRICANE WARNING SYSTEM—An announcement by Secretary of Commerce Mueller states that the Weather Bureau has installed new, and specially designed, high-powered weather radars along the Atlantic and Gulf Coasts, each with ability to scan a 200,000 square mile area. Powerful radars are now operating at Brownsville, Texas; Apalachicola, Miami, Daytona Beach, and Key West, Florida; Charleston, South Carolina; Wilmington, and Hatteras, North Carolina; Washington, D. C.; Nantucket, Massachusetts; and San Juan, Puerto Rico. Besides the Weather Bureau stations, Bureau radar specialists are permitted to man 31 Air Defense Command radar sites. Radars are used also at the Air Force's Atlantic Missile stations, and reconnaissance service is provided by both the Air Force and the Navy.

● HONOLULU MAGNETIC AND SEISMOLOGICAL OBSERVATORY—The new Magnetic and Seismological Observatory, constructed at Ewa Beach, Island of Oahu, was dedicated on June 23. This new observatory of the U. S. Coast and Geodetic Survey will serve as the principal geomagnetic station in the Pacific, and will be an important link in the Survey's program of locating earthquakes throughout the World. It will continue to function in the Seismic Wave Warning System in the Pacific.

This observatory is one of ten such facilities operated by the survey.

● ARID ZONE PROBLEMS DISCUSSED IN PARIS—An international General Symposium on Arid Zone Problems was held at UNESCO House in Paris, May 11 to 18, 1960, attended by 250 scientists from 33 countries. The agenda included papers and reports on surface and subsurface hydrology, climatology, hydrometeorology, solar energy, saline water conversion, and methods of water conservation, in relation to the development of arid regions. UNESCO will publish the proceedings of the symposium in the *Arid Zone Research* series, and in both English and French.

● INTERNATIONAL CONFERENCE ON SCIENCE IN THE ADVANCEMENT OF NEW STATES—W. C. Lowdermilk, Past President of AGU represented the Union and presented a paper at a meeting of the International Conference on Science in the Advancement of New States, held in Rehoboth, Israel, in October. Lloyd V. Berkner, current President of AGU, also attended and gave a paper. The Conference was attended by representatives of many nations.

● AAAS MEETING, NEW YORK, DEC. 26–31—The preliminary program announcement of the New York meeting of AAAS includes a two-session symposium on the Impact of the Space Program on the Sciences, under auspices of the Planetary Sciences Committee of AGU, and arranged by Robert Jastrow of NASA, to be held on December 26.

Section E of AAAS will sponsor a symposium on the Moho project to drill a deep hole to the outer layer of the Earth's crust (see under Special Announcements).

● INTERNATIONAL CLOUD PHYSICS CONFERENCE—The dates for the Conference, to be held successively at Canberra, Australia, and Sydney, New South Wales, have been announced as September 11–21, 1961.

● REORGANIZATION OF COAST AND GEODETIC SURVEY EMPHASIZES RESEARCH—Organizational changes in the U. S. Coast and Geodetic Survey give greater emphasis to oceanography and research. Each of the four new Offices of Research and Development, Oceanography, Physical Sciences, and Cartography is now administered by an Assist-

ant Director, instead of a divisional chief, as formerly. The Office of Research and Development will coordinate and assist in applied research and development conducted by the various technical units, and will work closely with scientists in related fields in other parts of the Government, in universities and research institutions, and in private industry. The Office of Oceanography will monitor a comprehensive program of surveys and will embrace all technical oceanographic activities and supporting facilities, giving impetus for an expanded program in the field. The Office of Physical Sciences will specifically embrace activities in Geology, Geophysics, and Photogrammetry. The Office of Cartography is responsible for the production and distribution of charts for marine and air navigation to meet civil requirements and to provide for defense needs.

• SYMPOSIUM ON GEODESY IN THE SPACE AGE—A symposium, 'Geodesy in the Space Age', will be sponsored by the Institute of Geodesy, Photogrammetry and Cartography; the Division of Geodetic Science; and the Graduate School of the Ohio State University, February 6 to 8, 1961, to discuss (1) the problems the space age has brought to geodesy, (2) the most important developments needed to solve these new problems and (3) the education of the men who have to improve the techniques and solve the problems. The symposium will have five panels: Electronic Mensuration Methods; Physical Geodesy; Celestial Methods, including Satellite Geodesy; Photogrammetric Methods; and Needed Education. Chairman of the symposium will be W. A. Heiskanen, Director of the Institute of Geodesy, Photogrammetry and Cartography. It is anticipated that many leading men of Geodetic Science in America and abroad will participate. It is expected that the proceedings of the symposium will be printed.

Personalia

• WILLIAM N. ABBOTT, Assistant Professor at the University of Athens, Greece, participated in the NATO Summer School in Physics of the Upper Atmosphere, held on the Island of Corfu, June 27 to July 15.

• CHARLES A. ANDERSON of the U. S. Geological Survey has received the Distinguished Service Award of the Department of the Interior.

• ARTHUR A. BAKER of the Geological Survey, has received the Department of the Interior's highest honor, the Distinguished Service Award.

• JOSEPH BARTELS, of Göttingen, Germany, has been elected a Vice-President of the International Union of Geodesy and Geophysics.

• HENRY BRYANT BIGELOW, research oceanographer at Harvard University, and one of the founders of the Woods Hole Oceanographic Institute, has been awarded the first Henry Bryant Bigelow Medal, named in his honor, for outstanding work in his field.

• WILMOT H. BRADLEY, Research Geologist of the U. S. Geological Survey, and former Chief Geologist, has been honored by the American Journal of Science, in publication of a *Bradley Volume*.

• DETLEV W. BRONK, President of the National Academy of Sciences, has been awarded an honorary degree by the University of London.

• DAYTON CARRITT, formerly with the Chesapeake Bay Institute of The Johns Hopkins University, is now connected with the Woods Hole Oceanographic Institute and the Massachusetts Institute of Technology.

• ARTHUR S. COSLAR, JR., formerly with Melpar, Inc., and, earlier, Executive Director of the Mapping and Charting Research Laboratory of Ohio State University, has been appointed Deputy Director of the Intelligence Systems Division of Broadview Research Corporation, Burlingame, Calif.

• ARNOLD COURT, formerly Research Meteorologist with the U. S. Forest Service at Berkeley, Calif., and lecturer at the University of California, has been appointed Chief, Applied Climatology Branch, at the Air Force Cambridge Research Laboratories, Bedford, Massachusetts.

• DOAK C. COX, formerly with the Hawaiian Sugar Planters Association, has been serving as pro tem. coordinator for the tsunami research program at the Hawaii Institute of Geophysics in Honolulu. On completion of these temporary duties he expects to remain at the Institute to work in geology and hydrology.

• E. C. DAPPLES, Professor of Geology at Northwestern University, has been awarded a Senior Visiting Fellowship in Science, under the program of the Organization for European Economic Cooperation, administered by the NSF. He will visit the Universities of Lausanne and Geneva, in Switzerland.

• HANS A. EINSTEIN, of Berkeley, Calif., Fellow ASCE has received the J. C. Stevens Award of the American Society of Civil Engineers.

• ROBERT C. ELDERFIELD, Professor of Chemistry at the University of Michigan, has been appointed Chairman of the Division of Chemistry and Chemical Technology, National Research Council.

• WALTER M. ELSASSER, Professor of Theoretical Physics at the University of California, La Jolla, has been appointed Professor and Chairman of the Department of Physics at the University of New Mexico, Albuquerque.

• EDWARD P. ESPENSHADE, Jr., Chairman of the Department of Geography at Northwestern University, has been appointed Chairman of the

Division of Earth Sciences, National Research Council.

• MAURICE EWING, Director of the Lamont Geological Observatory at Columbia University, and former President of the AGU, was recently awarded the John Fleming Medal of the American Institute of Geonomy and Natural Resources in a ceremony held at the Woods Hole Oceanographic Institution. Dr. Ewing was cited for his research contributions in Earth Sciences, and his development of instruments for research, "of unique value to humanity in bringing knowledge about the oceans". The Medal is named for the late John Q. Fleming, well-known American geophysicist.

• NICHOLAS V. FEODOROFF, Associate Professor of Civil Engineering at Manhattan College, New York City, delivered a series of lectures at the Technological University, Delft, Holland, during the summer.

• MARSHALL C. HARRINGTON, formerly Head of the Fluid Dynamics Branch, has been appointed Contract Research Administrator at the U. S. Navy's David Taylor Model Basin.

• JOHN C. HOLLISTER, Head of the Department of Geophysical Engineering, Colorado School of Mines, has been elected First Vice-President of the Society of Exploration Geophysicists.

• CHARLES E. JACOB of Northridge, California, Consulting Engineer on water supply, has been appointed lecturer at the California Institute of Technology.

• W. C. JACOBS is now with the Library of Congress as a Science Specialist.

• JOSEPH KAPLAN of the University of California has been elected a Vice-President of the International Union of Geodesy and Geophysics.

• G. H. KEULEGAN retired on July 31 from the National Bureau of Standards after more than 38 years of service. He was awarded a U. S. Department of Commerce Gold Medal for his many outstanding contributions in the field of hydrodynamics.

• WILLARD F. LIBBY, Professor of Chemistry at the University of California (L.A.), has received a Nobel Prize in Chemistry for his use of radioactive Carbon-14 in determining the ages of plant and animal remains.

• JOANNE S. MALUS has left Woods Hole Oceanographic Institution and accepted an appointment as Professor of Meteorology at the University of California. She plans to work at WHOI during summers.

• ROBERT L. McFALL, formerly Assistant Engineer with the Division of Water Resources, Topeka, Kansas, is now Instructor in the Department of Agricultural Engineering, University of Illinois, Urbana, Illinois.

• ALVIN G. McNISH, Chief of the Metrology Division at the National Bureau of Standards, has been awarded a gold medal by the U. S. Department of Commerce for outstanding contributions in the fields of geomagnetism, ionospheric physics, metrology, and standardization.

• J. MURRAY MITCHELL, JR., has returned to his duties at the U. S. Weather Bureau, Office of Climatology, Washington, D. C., after completing doctoral requirement, and receiving his degree at Pennsylvania State University in June.

• IVAN I. MUELLER of the Institute of Geodesy at Ohio State University has been appointed Assistant Professor of Geodesy at the University.

• ARPAD LUDWIG NADAI, (retired), formerly with Westinghouse Research Laboratories, and one time consultant for the David Taylor Model Basin (U. S. Navy), and advisor on research projects for the National Academy of Sciences and National Research Council, has been awarded the Elliott Cresson Medal of the Franklin Institute for "original research adding to the sum of human knowledge."

• SVERRE PETERSSON, Professor of Meteorology at the University of Chicago, has been appointed Chairman of the Department of Meteorology.

• WILLIAM J. POWELL of the U. S. Geological Survey represented the AGU at the inauguration of Leslie Stephen Wright as President of Howard College, Birmingham, Alabama.

• ROBERT RAGOTZKIE, Assistant Professor of Meteorology at the University of Wisconsin, joined a research team in northern Manitoba in August, for the purpose of mapping Arctic lakes and studying their temperature ranges.

• NORRIS W. RAKESTRAW, of the staff of the Scripps Institution of Oceanography, has been appointed Associate Dean of the Graduate Division, La Jolla Campus, University of California.

• ROBERT H. RANDALL retired from the Federal Service on July 11, and is now Vice-President of the Aero Service Corporation of Philadelphia.

• JOHN C. REED, Director of the Arctic Institute of North America, and recently Staff Geologist of the Geological Survey, has received the Distinguished Service Award, highest honor conferred on employees of the Department of the Interior.

• GEORGE P. RIGSBY, formerly with the U. S. Navy Electronics Laboratory at San Diego, Calif., is now Senior Scientist with the Arctic Institute of North America at San Diego.

• ROBERT O. REID, of the Department of Oceanography and Meteorology, Texas A and M College, has been given a faculty distinguished achievement award, made annually to six faculty members by the Association of Former Students, selection being made by a faculty committee. Professor Reid, formerly with the Scripps Institution of Oceanography, has been on the A and M staff since 1950.

• GERHARD SCHILLING, former Chief of the Lunar and Planetary Sciences Programs at the National Aeronautics and Space Administration, is now with the Planetary Sciences Group, Engineering Division, of the Rand Corporation.

• FRED C. SCOBEY of Berkeley, Calif., consulting hydraulic engineer, has been awarded an honorary membership in the American Society of Civil Engineers; this is the highest award bestowed by the Society.

• LANSING G. SIMMONS of the Division of Geodesy,

U. S. Coast and Geodetic Survey, recently was awarded the Colbert Medal of the American Society of Military Engineers, for outstanding contributions to the advancement of military engineering through the development of basic techniques for geodetic and precision surveys.

• HENRY M. STOMMEL, Physical Oceanographer at the Woods Hole Oceanographic Institution, has been appointed Professor of Oceanography at Harvard University.

• VERNER E. SUOMI, Professor of Meteorology at the University of Wisconsin, spoke at the Helsinki meeting, in July, of the International Union of Geodesy and Geophysics on the results of the experiment using the satellite Explorer VII in giving a world weather pattern, and in measuring the Earth's loss of heat. He indicated that satellite measurements could be used in predicting weather, and in detecting storms in remote areas where there are no weather observers.

• W. F. G. SWANN, Director Emeritus of the Bartol Research Foundation, and physicist of world-wide recognition, was awarded the Elliott Cresson Medal by the Franklin Institute for his research in the field of cosmic radiation.

• JAMES S. SWEET, Hydraulic Engineer of the U. S. Weather Bureau, represented the World Meteorological Organization of Geneva, Switzerland, in the negotiations with the Peruvian Government at Lima, Peru, relating to the plan of operations for the Hydrometeorological Project for 1961–64. This Project is financed by the United Nations Special Fund, and will involve the establishing of hydrologic and meteorologic networks, and a hydraulic laboratory. The WMO is the executing agency for the Project.

• VICTOR VACQUIER, Research Geophysicist at the Scripps Institution of Oceanography, has recently been awarded a *John Price Wetherill Medal* by Franklin Institute, in recognition of his important inventions and developments in the field of magnetometer instrumentation.

• J. VAN MIEGHEM of the Royal Meteorological Institute of Belgium, and Chairman of the Belgian National Center for Polar Research, has been awarded the annual International Meteorological Organization Prize for scientific eminence and contributions. The Prize consists of a gold medal, $1200, and a diploma.

• THEODORE VON KARMAN, Chairman of the Advisory Group on Aeronautical Research and Development for NATO, received the Lamme gold medal for distinguished contributions to engineering education and research at the annual meeting of the American Society for Engineering Education, held recently at Purdue University.

• CHARLES A. WHITTEN of the U. S. Coast and Geodetic Survey was elected President of the International Association of Geodesy, at the 12th General Assembly of IUGG held at Helsinki in July.

• J. P. WOODS, Director of the Geophysical Laboratory of the Atlantic Refining Co., Dallas, has been elected President of the Society of Exploration Geophysicists.

• WILLIAM E. WRATHER, former Director of the U. S. Geological Survey, has been elected to Honorary Membership in the American Institute of Mining and Metallurgical Engineers.

• HAROLD LATTIMORE ALLING, retired, Professor Emeritus of Geology and formerly head of the Dept. of Geology at the University of Rochester, died on July 27, 1960. He was born in Rochester, New York, February 7, 1888. He received a B.S. degree from Rochester in 1915, and M.A., and Ph.D. degrees from Columbia University in 1917 and 1920, respectively, specializing in Geology. He served on the geologic staff of the N. Y. State Museum 1917–20. In 1920 he became Instructor in Geology at the University of Rochester and rose rapidly to a full professorship. He became Director of Ward's Natural Science Establishment, in Rochester, when that organization was taken over by the University in 1931, and served in that capacity until 1940. From 1927 to 1932 he was Chairman of the Feldspar Committee of National Research Council. He was a Fellow of the Geological Society of America and of the Mineralogical Society of America, and a member of the American Association for the Advancement of Science, the American Geophysical Union, the Geochemical Society, the New York Academy of Sciences, and the American Institute of Mining, Metallurgical, and Petroleum Engineers. His research work and writings were largely in the fields of interpretative geology of igneous rocks, crystallization of rock-forming minerals, sedimentary petrography, and ore deposits. His major reports dealt with Silurian salt deposits of New York, graphite deposits and Precambrain stratigraphy and structures of the Adirondacks, and lavas of the Fiji Islands He had been a member of AGU since 1934.

• JOSEPH W. BROOKHART, District Geologist, Ground Water Branch, United States Geological Survey in North Dakota, died suddenly at Grand Forks on May 29, 1960, at the age of 44. He was a son of the late Senator Smith W. Brookhart of Iowa, and was born at Washington, Iowa, July 10, 1915. He was educated in public schools in Washington, D. C. He attended the George Washington University, and the University of Chicago, where he received his B.S. degree in Geology in 1940, followed by post-graduate work at The Johns Hopkins University. At the outbreak of World War II he was a bomber pilot, and participated in the evacuation of the Philippines during the Japanese invasion. Later he took part in bombing raids on targets in New Guinea, New Britain, and other parts of the Southwest Pacific Areas, where he distinguished himself in combat. He was awarded the Silver Star with an Oak Leaf Cluster, the Distinguished Flying Cross, the Air Medal, and a Presidential Unit Citation. After the war he joined the Geological Survey and served with the Topo-

graphic Division for a short time before transferring to the Water Resources Division to undertake ground-water investigations, first in North Dakota, and later in Maryland. In 1951, he was sent to Guam to undertake the difficult and important task of appraising the ground-water resources of that military base. Upon completion of that assignment he became District Geologist for North Dakota, a position which he held until his untimely death. Throughout his career with the Geological Survey, Joe Brookhart displayed to an unusual degree the combination of scientific and administrative ability that made it possible for him and his assistants, using all the tools available to the modern geologists, to clarify geologic and hydrologic problems that had puzzled many of his predecessors. Mr. Brookhart had been a member of AGU since 1953.

• LEWIS A. JONES, Consultant in drainage engineering, died on March 24, 1960, at his home, 7131 Chestnut St., N. W., Washington, D. C. He was born in St. James, Minn., December 20, 1885. He received a C. E. degree from the Univ. of Minnesota in 1907. In 1909, he joined the staff of the Dept. of Agriculture as junior drainage engineer. In 1931 he became chief of the Div. of Drainage and Erosion Control, and in 1942, Chief of the Div. of Water Conservation and Disposal, Soil Conservation Service. He retired in 1952 and entered private practice as a Consultant. He received the Dept. of Agriculture award for distinguished services. He was a member of ASCE, a Fellow of the Soc. of Agricultural Engineers, and for many years a member of AGU.

• ROBERT E. TURNER, for many years Plant Engineer at the Susquehanna Electric Co., Conowingo, Md., died suddenly on February 27, 1959, at the age of 57. He was born on Odebolt, Iowa. He received the degree of B. S. in Electrical Engineering from Iowa State College in 1921 and a professional degree in Civil Engineering from the same institution in 1946. At various times he took advanced study at the University of Pennsylvania, The Johns Hopkins University, and Worcester (Mass.) Polytechnic Institute. During his professional career he was associated with numerous large power and electric companies from the east to the west coasts. For 25 years he was a member of Pennsylvania Electric Association, Hydraulic Power Committee, serving for some time as Chairman. He was a member and one-time chairman of the ASCE Power Division Subcommittee on Operation and Maintenance of Hydro-Electric Stations and was awarded the James W. Rickey Medal by that division for his paper on Operation of the Conowingo Hydro Station. He was a member of the American Meteorological Society, and of the AGU since 1939.

Union, Section, and Committee Activities

Minutes of Special Meeting of the Executive Committee, American Geophysical Union, July 27, 1960

The meeting was called to order at 16h 00m on July 27, in Room 1.10 of the University of Helsinki, Finland, by President Lloyd V. Berkner.

Present—P. H. Abelson, W. C. Ackermann, K. H. Beij, L. V. Berkner, Miss Bruhn, W. H. Bucher, Perry Byerly, E. G. Droessler, Maurice Ewing, B. F. Howell, Jr., Robert Jastrow (for Homer Newell), J. W. Joyce, Joseph Kaplan, E. C. LaFond, H. E. Landsberg, W. B. Langbein, R. K. Linsley, John Lyman, T. F. Malone, W. H. Munk, A. O. C. Nier, Hugh Odishaw, Charles Pierce, D. W. Pritchard, F. W. Reichelderfer, A. N. Sayre, J. F. Schairer, M. O. Schmidt, A. H. Shapley, Andre C. Simonpietri (for W. W. Atwood, Jr.), Waldo E. Smith, E. H. Vestine, C. A. Whitten, and Ralph N. Wilson. The following were in Helsinki but were unable to attend owing to prior commitments: L. R. Alldredge, L. T. Aldrich, J. R. Balsley, H. R. Byers, C. T. Elvey, Irving Friedman, W. D. Lambert, L. M. Murphy, J. H. Nelson, Frank Press, R. R. Revelle, L. B. Slichter, H. G. Wilm, and G. P. Woollard.

As this was a special meeting, the minutes of the last meeting held April 25 and 29, 1960, were not considered for approval but will be considered on the agenda of the next regular meeting.

Under date of June 22, 1960, a ballot was sent to the Executive Committee relative to changes in the Statutes and By Laws. Although the mail ballot overwhelmingly approved the changes as set forth, a few minor questions were raised concerning details, and the Proposal was modified slightly to meet the questions that had been raised by S. D. Cornell, Executive Officer of the National Academy of Sciences. The changes were approved and the President was instructed to advise Cornell of these changes, which likewise affected the information sent to the members in mid-August for ballot as set forth in the September 1960 issue of the *Transactions* (pp. 486–487).

The principal purpose of this special meeting was to hear and take action on the reports of the various Committees on Nominations. Chairman Walter H. Bucher noted that his Committee on Nominations for Union officers recommended the nomination of Thomas F. Malone for President, Charles A. Whitten and George P. Woollard for Vice President, and A. Nelson Sayre for General Secretary. The report was unanimously adopted. The reports of the Committees on Nominations of the Sections were also in hand, and the Section officers reported nominations as follows:

Geodesy—Floyd W. Hough, President; Charles A. Whitten, Vice President; Buford K. Meade, Secretary

Seismology—James A. Peoples, Jr., President; Jack E. Oliver, Vice President; B. F. Howell, Jr., Secretary

Meteorology—Francois N. Frenkiel and Walter Orr Roberts, President; Henry G. Houghton and William W. Kellogg, Vice President; Woodrow C. Jacobs, Secretary

Geomagnetism and Aeronomy—C. T. Elvey, President; E. H. Vestine, Vice President; J. H. Nelson, Secretary

Oceanography—Clifford A. Barnes and Donald W. Pritchard, President; Robert S. Arthur and Dayton E. Carritt, Vice President; Charles D. Bates and Arthur E. Maxwell, Secretary

Volcanology, Geochemistry, and Petrology—Hatten S. Yoder, Jr., President; Edward D. Goldberg, Vice President; David R. Wones, Secretary

Hydrology—William C. Ackermann, President; Alfred J. Cooper and David K. Todd, Vice President; Ralph N. Wilson, Secretary

Tectonophysics—Louis B. Slichter, President; David T. Griggs, Vice President; Iris Borg, Secretary. Nominees for two members of the Executive Committee—George A. Thompson and Patrick M. Hurley

Nominations for Regional Committees were reported as follows;

Pacific Southwest Regional Committee (Arizona, California, and Nevada)

Hydrology—Arthur F. Pillsbury, Joseph F. Poland, David K. Todd

Oceanography—Charles S. Cox, Jacob S. Wickham

Meteorology—W. D. Duthie, Robert E. Holzer, Morris Neiburger

Geomagnetism and Aeronomy—E. H. Vestine

Pacific Northwest Regional Committee (Idaho, Montana, Oregon, Washington, and Wyoming)

Geodesy—Fred Natella

Seismology and Tectonophysics—Robert DeLuccia

Meteorology (two to be elected)—Robert Beaumont, Lenard Bissell, Fred Decker

Geomagnetism and Aeronomy, and *Volcanology, Geochemistry, and Petrology*—Keith E. Anderson

Oceanography—Robert Paquette

Hydrology (three to be elected)—Charles L. Barker, Hollis Orem, Robert Russell, Meredith Thoms

North Central Regional Committee (Minnesota, Iowa, Missouri, North Dakota, and South Dakota)
Nominations pending.

It was noted that plans for the December 1960 issue of the *Transactions* include a detailed report on the Helsinki meeting, Association by Association, and for the Union as a whole. This plan developed before the beginning of the General Assembly and, put into operation, contemplates that each Section President will serve as editor to get the material for the particular Association into shape, and that the Chairman of the Committee on International Participation will do the same for the Union as a whole. An appeal for cooperation to attain these goals was made, and preliminary reports indicated that, for the most part, the assignment of reporters for the various sessions had been made and that this work was going ahead according to plan.

It was reported that the financial statement on the old basis is in hand, and that the statement on the new basis was expected before the end of the General Assembly. As soon as the new basis is operating as a matter of routine, it is anticipated that monthly statements to the officers will keep them up to date with regard to the status of various projects and accounts.

It was reported that the contemplated reorganization in the office aimed towards departmentalization of the work has taken place and that the shaking down of details in this reorganization is now under way.

There was brief discussion of a nuclear test detection activity and the VELA program, with a meeting to be held in Washington in October.

The meeting adjourned at 17h 45m.

A. NELSON SAYRE, *General Secretary*
WALDO E. SMITH, *Executive Secretary*

Geophysical Society of Hawaii

The Geophysical Society of Hawaii, the Mid-Pacific regional group of AGU, held a meeting on September 22, at which reports on the Helsinki meetings of IUGG were made by five of its members who attended and participated at those meetings. Reports were given by T. S. Austin, on oceanography; D. C. Cox, on tsunamis and seismology; John Mink, on general impressions; C. S. Ramage, on meteorology; and F. N. Visher, on hydrology.

The Society also held a meeting on November 22, in Honolulu, at which Jerome Namias, Chief of the Extended Forecast Section of the U. S. Weather Bureau, Washington, D. C., discussed the interactions between land, sea, and air that are germane to long-range weather forecasting.

Pacific Northwest Regional Meeting

The seventh annual meeting of the Pacific Northwest Regional Branch was held at the University of Idaho, Moscow, Idaho on October 19–20, 1960. Registration included approximately 45 members, and 25 students and guests. The four sessions consisted of 17 papers lead off by W. C. Ackerman, Vice-President of Hydrology Section, AGU, who spoke on 'Needed: Three Wise Men.' At the banquet Wednesday evening, Prof. Elwyn S. Schwartz of the University of Idaho, addressed the group on 'Serendipity'. Waldo Smith, Executive Secretary of AGU, spoke to the noon luncheon-business session on the national AGU activities and plans.

During the business session the Regional Committee presented three proposed amendments to the Statutes and By Laws. The first two amendments are to facilitate the change of responsibility from the old committee to the new committee in an election year. Because planning for the annual meeting is well under way by July 1, (the old beginning date of the term of office) the change from old committee and officers to the new has been complicated. Under the proposed changes the term of office of the committee members and officers would begin January 1, and all planning for the fall meeting could be handled by the new committee. The third proposed amendment changes the title of the executive body of national AGU from 'Executive Committee' to 'Council' in our Statutes and By Laws, so as to confirm with the change in the national Statutes and By Laws. Balloting will be by mail. The present publication policy of the AGU and current plans for better serving the hydrologists were discussed at length. The group approved the Regional Committee's recommendation to hold the 1961 meeting in Portland, Oregon.

Special Announcements

● FORTY-SECOND ANNUAL MEETING OF THE AMERICAN GEOPHYSICAL UNION TO BE HELD IN WASHINGTON, D. C., APRIL 18–21, 1961, INCLUSIVE—As announced in the September issue of the Transactions the Forty-Second Annual Meeting will be held on the above dates; this precedes the meetings of the National Academy of Sciences which are scheduled for the following week.

Plans for the programs of the various Sections are developing rapidly. There will be general meetings of the Union as a whole, including a smoker scheduled for Wednesday evening, April 19, and the Award of the William Bowie Medal and a lecture on Thursday evening, April 20.

Suggestions with respect to the Section meetings and to the Union as a whole are invited. Suggestions for the Union meeting should be sent to L. T. Aldrich, Chairman, Committee on Meetings, AGU, 5241 Broad Branch Road, N.W., Washington 25, D. C. For information regarding Section meetings, consult the list of Section Secretaries and Program Chairmen below.

This announcement will also serve as an invitation for members and others to send word of plans for papers to be presented. Titles of papers with three copies of abstracts should be sent in as soon as possible and not later than February 1, 1961. (The closing date for Meteorology is January 9, 1961, and for Hydrology, January 1, 1961, see the special notes below. See also special notice for proposed Planetary Sciences Program, below.) Please give information concerning the time required (most papers are allowed from 10 to 20 minutes.) This information should be sent to the office of AGU at 1515 Massachusetts Avenue, N. W., Washington 5, D. C., or to the Secretary or Program Chairman of the appropriate Section as follows:

Geodesy, Buford K. Meade, U. S. Coast and Geodetic Survey, Washington 25, D. C., or Erwin Schmid (Program Chairman), U. S. Coast and Geodetic Survey, Washington 25, D. C.

Seismology, Benjamin F. Howell, Jr., Geophysical Laboratory, Mineral Sciences Building, Pennsylvania State University, University Park, Pennsylvania.

Meteorology, Woodrow C. Jacobs, 3812 Nash Street, S. E., Washington 20, D. C., or, Paul Kutschenreuter, U. S. Weather Bureau, 2400 M St., N.W., Washington, D. C.

Geomagnetism and Aeronomy, J. Hugh Nelson, Geophysics Division, U. S. Coast and Geodetic Survey, Washington 25, D. C.

Oceanography, Eugene C. LaFond, Code 2235, U. S. Navy Electronics Laboratory, San Diego 52, California.

Volcanology, Geochemistry, and Petrology, Irving Friedman, 6209 Wagner Lane, Washington 16, D. C.

Hydrology, Charles C. McDonald, U. S. Geological Survey, Box 1488, Yuma, Arizona, or Harry E. Schwarz (Program Chairman), 315 Ladson Road, Silver Spring, Maryland.

Tectonophysics, H. Richard Gault, Department of Geology, Lehigh University, Bethlehem, Pennsylvania.

Section program planners reserve the right to close filled programs in advance of the dates indicated, so please make it a point to send word in early. Also, in some Sections, specific themes are being developed, and it is possible that if a particular paper fails to fall within one of these themes and the sessions for general papers are already closed, it may not be possible to include such papers. Abstracts of papers that are to be presented will be published in the program.

Remember that an abstract is an opportunity to bring the important results of your work to all those who see the program. The abstract should be concise and at the same time comprehensive and informative, and must not exceed 200 words (see Suggestions to Authors in the *Transactions* of April 1957, page 285, for ideas regarding abstracts). Longer abstracts will be reduced to 200 words or omitted at the editor's discretion. Please advise, in sending in the abstract, what projection equipment will be needed. Standard slide projectors (3—¼ × 4 inches) will normally be available at the meetings, but other facilities will be provided only if especially requested well in advance. In making slides, avoid crowding and attempting to show too much on one slide. More than two or three curves on a slide tend to be confusing. Large-size lettering is essential. Complete manuscripts are not necessary but are desired and should be forwarded to the office of AGU by April 15 in order to be available to science news writers. Please indicate whether the paper is being submitted for the program only or also for consideration for publication in the *Journal of Geophysical Research*.

If a paper is written in collaboration, please indicate by whom it is to be presented. Arrangements can sometimes be made with the Section Secretary or Program Chairman for the presentation of papers of authors who are unable to attend, but papers that are to be presented by title only are excluded from the program.

Make hotel or room arrangements directly with the hotel of your choice at an early date. If you fail on the first attempt, bear in mind that advance bookings that are not taken up are generally canceled by hotels about two weeks in advance. Thus a follow-up request on or before March 1 may bring a desired response. We are making block bookings at two hotels as follows:

Roger Smith Hotel, Pennsylvania Avenue at 18th Street, N.W.
Roosevelt Hotel, 2101 16th St. N.W.

If you write to one of these hotels refer to the AGU block booking.

Special notice regarding Meteorology—The Section of Meteorology will meet jointly with the American Meteorological Society. Paul Kutschenreuter and Woodrow C. Jacobs are co-chairman of the Joint Meteorological Program Committee. All abstracts must be received by January 9.

Special instructions regarding Hydrology—Specific plans are being made in Hydrology to avoid the overcrowding that has characterized previous meetings. In order to afford opportunity to a large number of hydrologists to present their work, the papers are to be screened to select a number for full-length presentation. All others will be presented as five-minute summaries without discussion. This procedure has been adopted to permit more detailed discussion of subjects of broader interest and at the same time to provide a suitable forum for short presentation of other timely subjects. The summary due on January 1 may be informal, and the condensed 200-word abstract can be prepared in the ensuing month so that Program Chairman Schwarz will have these in hand by February 4. The *ad hoc* Committee will attempt to notify authors by January 25 as to whether a particular paper is to be presented as a five-minute summary or in full. Request is made for the papers selected for full-length presentation to be available to the Program Chairman by the beginning of the meeting at the very latest.

Special notice regarding proposed planetary sciences program—The AGU Planning Committee on Planetary Science is arranging sessions on the topics listed below for the April 1961 meeting in Washington. Abstracts for papers to be read in these sessions should be sent before February 20, 1961 to Robert Jastrow, Theoretical Division, Goddard Space Flight Center, 8719 Colesville Road, Silver Spring, Maryland. The abstracts should not exceed 200 words in length. Sessions marked with an asterisk will be sponsored jointly by the Planetary Science Committee and the Geomagnetism and Aeronomy Section. Copies of abstracts for these joint sessions should be sent to both Dr. Jastrow and Hugh Nelson, Coast and Geodetic Survey, Washington, D. C., by February 20, 1961.

*1. Trapped Particles
   a. Properties
   b. Geophysical Effects
2. Interplanetary Plasma
*3. Solar Cosmic Rays and Their Atmospheric Effects (including polar absorption)
*4. Hydromagnetic Waves
5. Structures of Moon and Planets
6. Solar Physics
*7. Atmospheres of the Planets
8. Theoretical Physics
9. Instrumentation for Space Physics

• PACIFIC SOUTHWEST REGIONAL MEETING—Plans are progressing for the Regional Meeting, which is to be held at the University of California, Berkeley, on January 26–27, 1961. Those interested in participating should send titles and abstracts, not later than December 1, 1960, to the Program Chairman, Henry W. Anderson, PSW Forest and Range Experiment Station, P. O. Box 245, Berkeley 1, Calif. Sessions are planned for Sections of Hydrology, Meteorology, Geomagnetism and Aeronomy, and Oceanography. Sessions for other Sections will be scheduled if interest develops. Paul R. Day, Univ. of California (Berkeley) is Chairman of the Local Arrangements Committee.

• TENTH PACIFIC SCIENCE CONGRESS—The program for the Section of Geophysical Sciences of the Tenth Pacific Science Congress, to be held August 21–September 6, 1961, at the University of Hawaii, Honolulu, will include many symposia papers, besides sessions for contributed papers and reports. (See September *Transactions*, p. 487, for list of Symposia subjects). The program for the Section is under the direction of Lloyd V. Berkner, President of AGU. Division Organizers are: *Meteorology and Upper Atmosphere*—C. E. Palmer, Inst. of Geophysics, University of California, Los Angeles 12, Calif., and C. S. Ramage, Dept. of Meteorology, University of Hawaii, Honolulu 14, Hawaii; *Oceanography*—Walter H. Munk, Scripps Institution of Oceanography, University of California, La Jolla, Calif., and Thomas S. Austin, U. S. Fish and Wildlife Service, Honolulu, Hawaii; *Solid Earth Sciences*—Gordon A. MacDonald, Dept. of Geology and Geophysics, University of Hawaii, Honolulu 14, Hawaii.

Those who desire to present scientific papers should submit summaries to the Division Organizers, not later than March 31, 1961. Summaries must be in double-spaced typing, in duplicate, and comprise 300 to 1000 words; also they must bear the name address, title, and affiliation of the author. Five to fifteen minutes will be allowed for presentation. State amount of time needed, or if it is to be read by title only.

Interesting post-sessional field trips have been planned to Kauai, to Mauna Loa, Kilauea, and Haleakala Crater, and to the Astrophysical Laboratory.

More detailed information may be obtained by writing to Harold J. Coolidge, Sec'y-General, National Academy of Sciences, Washington 25, D C

The National Science Foundation is cooperating with the Pacific Science Board of the National Academy of Sciences to support travel of American scientists to the Congress. Individual grants will be limited to a round trip air tourist ticket, home city to Honolulu. Preference will be given to those invited to participate in symposia in the fields of the Physical, Biological and Social Sciences, and research in the Antarctica, and in dissemination of information among scientists. Apply by letter to Pacific Science Board, National Academy of Sciences, 2101 Constitution Ave., N. W., Washington 25, D. C., by 15 January; notification of action will be sent about 15 February.

• CORRIGENDUM—On page 487 of the September 1960 issue of Transactions, under item Tenth Pacific Science Congress, the year of the Honolulu meeting should be 1961, *not* 1960; it will then accord with the statement on page 488 in re the International Cloud Physics Conference.

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NATIONAL ACADEMY OF SCIENCES

Number 40 • October 1960

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Rocket-Grenade Measurements of Temperatures and Winds in the Arctic Mesosphere

The following report is based on material by W. G. Stroud, W. Nordberg, W. R. Bandeen, F. L. Bartman, and P. Titus. Stroud, Nordberg, and Bandeen were with the U. S. Army Signal Research and Development Laboratory when the experiment was conducted; they are now with the National Aeronautics and Space Administration. Bartman and Titus are at the University of Michigan. A more complete account was published in the Journal of Geophysical Research, *August 1960.*

In an effort to develop a model of atmospheric behavior in the 30 to 90 km region, rocket-grenade experiments were used during and just prior to the IGY to obtain temperature and wind measurements in three typical areas of the globe. The experiments were conducted at White Sands, New Mexico, in middle latitudes; at the arctic rocket facility at Fort Churchill, Canada; and at the equatorial Western Pacific island of Guam. This report deals with results of IGY rocket launchings at Fort Churchill during November 1956, July, August, and December 1957, and January 1958. Some comparisons are made with the White Sands data of 1950–53; results of the Guam program of November 1958 are not yet available.

In the Fort Churchill experiment, 10 Aerobee rockets carried aloft and ejected 18 or 19 high-explosive grenades each. A total of 150 measurements were thus obtained, each representing the average temperature and wind vector of an atmospheric layer about three kilometers thick (between two exploded grenades), as follows:

The position in space and the time of each explosion were determined through electronic tracking, and an array of microphones on the ground recorded the arrival of the sound waves. Mathematical analysis of the times and positions of the explosions and the times and angles of arrival of the sound waves indicated the average direction and speed of the wind that displaced the sound waves during their trip to the ground. When this wind-vector data is known, the speed of sound in the layer can be computed; from this and from independently known factors such as the molecular weight of the medium, the temperature can then be calculated.

Temperature Results

The temperature results show that in summer as well as in winter the mesopeak occurs at about 50 km. (The mesopeak is the temperature maximum in the mesosphere, where temperatures rise with altitude as a result of strong absorption of solar

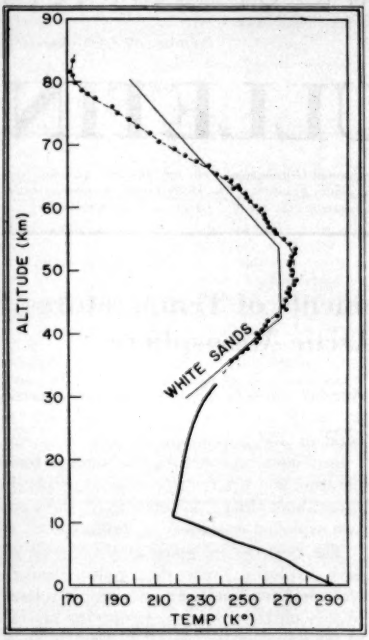

Fig. 1. *Summer Temperature Averages from IGY Rocket-Grenade Experiment at Fort Churchill, Canada. Dots represent running averages from five flights, in July and August 1957; heavy line represents averages from balloon data; and light line shows data from experiments at White Sands, New Mexico, for comparison.*

radiation by the ozone layer, reach a peak, and then fall to the lowest values measured in the atmosphere before beginning a more-or-less continuous rise with increasing height; the mesosphere extends from a height of about 30 km—the top of the stratosphere—to about 82 km.)

In summer (see Fig. 1), there is a nearly linear increase in temperature from about 220° Kelvin at the tropopause (about 11 km) through the stratosphere and lower half of the mesosphere to 275°K at 50 km; in winter (see Fig. 2), however, a slightly negative temperature gradient prevails from 17 to 27 km, with a minimum of about 207°K being reached at the latter height before temperatures again begin to rise. Between 30 km and the mesopeak, temperature gradients are about equal in winter and summer—about 2.5°K per km. However, actual temperatures in this region are about 25° to 30°K higher in summer than in winter. Above the mesopeak, this seasonal difference is reversed.

In winter, there are no pronounced average temperature gradients between the mesopeak and the ceiling of the measurements, at 90 km. In summer, the temperature drops sharply and almost linearly from about 275°K at 53 km to about 170°K at the mesopause (top of mesophere), at 82 km. The difference between the highest measured temperature at 75 km (winter 1957) and the lowest one (summer 1957) at that altitude is 90°K.

A remarkable seasonal variation is evident in both magnitude and altitude distribution of temperatures. The entire summer temperature curve is extremely smooth compared to the scattering that occurs for the region above the mesopeak in winter time. The very stable summer arctic atmosphere between 50 and 90 km thus contrasts with the dynamically very active and unstable medium during December and January. This instability is especially well demonstrated by two pairs of launchings in December 1957 and January 1958. Data from flights on both December 11 and 14, 1957, show a second temperature peak at about 70 km in which the maximum temperature fell from about 290°K on the 11th to about 245°K on the 14th.

The other good example of such an unusual temperature maximum is found in results of the two launchings on January 27, 1958. In both, a sudden temperature rise from approximately 235°K at 75 km to 250°K at 80 km was observed. The second

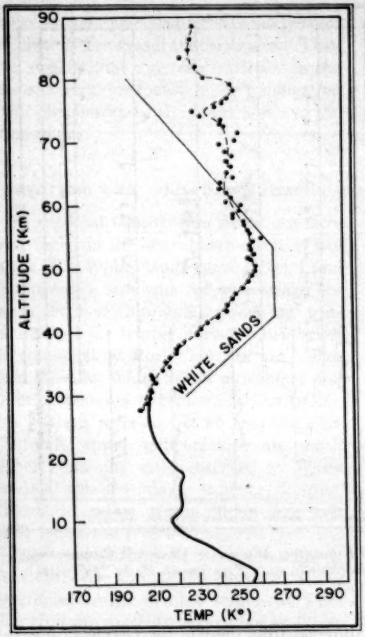

Fig. 2. *Winter Temperature Averages from IGY Rocket-Grenade Experiment at Fort Churchill, Canada. Dots represent running averages from five flights, in November 1956, December 1957, and January 1958; heavy line represents averages from balloon data; and light line shows data from experiments at White Sands, New Mexico, for comparison.*

of these two rockets also carried a falling-sphere experiment as an independent technique for simultaneous atmospheric density measurements. This experiment was successful and the temperature data derived from the density measurements compare well with those from the grenade data. One of these two launchings was conducted at midnight and the other at the following noon in order to observe possible daily variations. With the exception of a possible temperature increase on the order of 5°K from midnight to noon in the 50- to 60-km region, no variations in wind or temperature could be found.

No further daily temperature variations could be deduced from any other winter launchings because, even if they existed, such variations would have been obscured by the much larger ones mentioned above. Below 50 km, where there is less scattering of temperatures, no daily effects could be found.

An analysis of results of the summer launchings also seems to indicate that temperatures at 50 km might be lower by 5° to 10°K during the first half of the day (0000 to 1200) than during the second half (1200 to 2400). However, since only five launchings were made and they were spread over more than one month, these results are not very conclusive. The wind pattern does not show any daily changes at all.

Winds

In contrast to the temperatures, the winds generally show a less unexpected pattern, except during two launchings on January 27, 1958. In general, strong westerly winds prevailed in November and December, and moderate winds from the east were observed in July and August. Wind speeds as high as 165 meters per second from the west were measured in the winter (November 12, 1956), and maximum east winds on the order of 80 m/sec were measured in the summer (August 12, 1957); in general, however, summer wind speeds remained below 50 m/sec. (See Figure 3.)

Wind measurements from both rockets launched on January 27, 1958, were highly unusual and do not seem to fit into the general pattern of strong winds from the west during the winter months. During the last week of January 1958, one of the now-well-known "explosive" stratospheric warmings first observed by R. Sherhag in 1952 spread

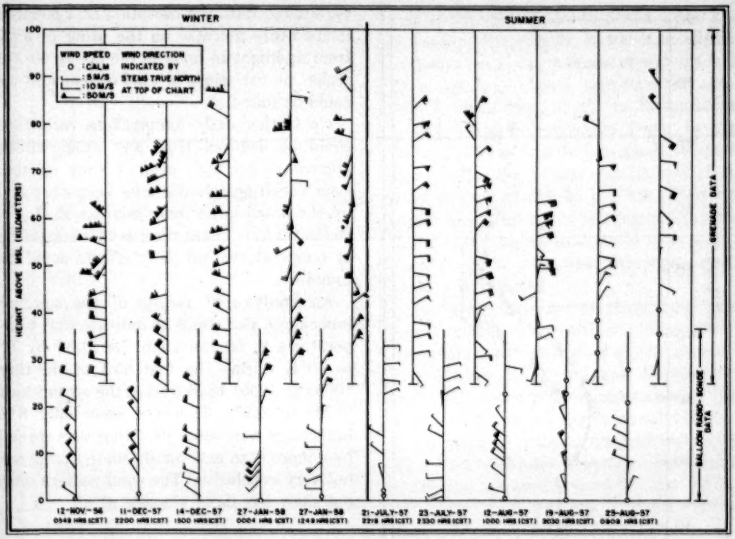

Fig. 3. *Wind Vectors to an Altitude of About 90 Kilometers Above Fort Churchill, Canada, in Winter and Summer, as Obtained in the IGY Rocket-Grenade Experiment. Barbs "fly" with the wind; velocities indicated as shown at upper left.*

westward over northern Canada. (These warmings generally occur between January and March and are believed to indicate a breakdown of the winter-time polar vortex in the stratosphere.)

Although the warming was not yet observed on January 27 at ground level at Fort Churchill, data from the launchings on that day show that breakdown of the winter vortex had in fact taken place at higher altitudes. Winds from the northeast prevailed up to an altitude of 45 km, where the wind direction reversed suddenly and became southerly. The southerlies definitely prevailed up to 75 km, and even above this altitude there was no sign of the usual wintertime westerly circulation.

Temperatures obtained both from balloon soundings over Fort Churchill and from the rocket data for this date were not essentially different from those of the December observations. Two days later, however, rocket measurements of atmospheric density above Fort Churchill by, L. M. Jones, J. W. Peterson, E. J. Schaefer, and H. F. Schulte, indicated an enormous temperature rise in the 30–45 km region but none at lower levels. In another few days (February 3, 1958), some warming was observed at stratospheric levels. Unfortunately, no wind data were obtained for the mesosphere over Fort Churchill after January 27th, but it is generally thought that the polar vortex is not fully restored after such a breakdown. C. E. Palmer points out that on this particular occasion, however, a weak polar vortex was restored in March 1958.

The rocket data clearly demonstrate in this case that the breakdown in stratospheric circulation and the accompanying

warming were preceded by a breakdown of circulation throughout the mesosphere. They also suggest that dynamic processes in the mesosphere are responsible for propagating these phenomena to the lower levels of the atmosphere.

Comparison with White Sands Results

No seasonal temperature variations have been found in the mesosphere above White Sands. The White Sands curve (Figs. 1 and 2) represents somewhat of an average between the Fort Churchill summer and winter curves: the temperatures at and below the mesopeak at Fort Churchill are higher than those at White Sands in summer and lower in winter, and between 50 and 80 km, this pattern reverses. At 80 km, the Fort Churchill winter temperatures are much higher than any ever observed at White Sands at this altitude. In summer, the Fort Churchill temperatures at 80 km are about 30°K below the White Sands average.

The wind pattern at Fort Churchill is qualitatively similar to that at White Sands, although winter winds at Fort Churchill are much stronger than at White Sands. Summer winds at both latitudes are approximately of the same magnitude.

Conclusions

The uniform temperatures measured during July and August 1957 appear to show thermal equilibrium during this period. The investigators conclude, therefore, that temperatures throughout the mesosphere are determined by radiation processes at these latitudes during the summer. For the region above the mesopeak, these arctic summer temperatures are much lower than summer temperatures at middle latitudes. This should make it easier to calculate the concentration and behavior of photochemically active atmospheric constitutents, such as ozone (O_3), at these altitudes. It might be further concluded that the finding that the O_3 concentration shows a very strong latitudinal dependence at lower altitudes also holds true for altitudes all the way up to 90 km. This is especially important since O_3 is believed to be in photochemical equilibrium above 40 km, and any latitudinal variation must therefore be brought about directly by radiation.

The high and unexpectedly irregular temperatures during the winter months, on the other hand, suggest that dynamic processes, specifically subsidence (a descending motion of air, usually over a broad area), are responsible for the thermal state of the mesosphere in the winter. It would be difficult to derive an atmospheric model to explain the results of the winter launchings strictly on a radiative basis. The unusual results of the two January 27th launchings also support this picture of dynamically controlled temperatures.

The very low temperatures observed in summer at 80 km may shed new light on the formation of noctilucent clouds, which are observed predominantly in the northern sky in summer at about this altitude. These temperatures (about 170°K) correspond approximately to the radiation-equilibrium temperature of 166°K cited by E. H. Vestine and D. Deirmendjian for condensation-nuclei near the earth, on the dark side. Vestine and Deirmendjian point out that, at 80 km, sufficient energy is communicated in collisions between atmospheric molecules and the nuclei particles to cause the latter to assume nearly the same temperature as the atmosphere in which they are suspended. At higher altitudes, radiation may be the dominant factor and the particles would no longer have the same temperature as the surrounding air.

Thus, at 80 km, the condensation nuclei and surrounding atmospheric gas are at the same low temperature; at higher altitudes these temperatures differ because of radiation, and at lower altitudes the temperatures are too high to support condensation. The 170°K temperature detected at

this height in the rocket experiment is sufficiently low to cause condensation on these nuclei of even the small amounts of water vapor present.

It is further concluded from the measurements at Fort Churchill and White Sands that the circulation from about 80 km down follows very closely the circumpolar pattern found to exist at lower altitudes in the stratosphere. Although this pattern does not reflect the characteristic day-to-day variation of meteorological elements in the troposphere, it is affected by large-scale seasonal events such as the reversal in circulation from summer to winter, and vice versa, for which the results of the flights on January 27, 1958 serve as an especially good example.

The fact that such seasonal events can be observed to altitudes nearly up to the base of the ionosphere (about 82 km) suggests very strongly that large-scale meteorological events are not limited to either the troposphere or the stratosphere, or to both, but also involve higher atmospheric levels. Moreover, the chronological sequence of the spreading of abnormally high temperatures through the atmosphere shows that these events occur first at higher altitudes, and then penetrate downward toward the troposphere over a period of several days or weeks. Thus, these meteorological effects may be governed by events at altitudes above the range of this experiment, with the mesosphere serving only as a dynamic link in propagating them downward.

The view that the breakdown in circulation observed on January 27, 1958 is not caused by the absorption of extraterrestrial radiation in the region below 80 km is supported by the results of a study by L. R. Davis, O. E. Berg, and L. H. Meredith. Their measurements of auroral-particle radiation, during a rocket flight at Fort Churchill on January 25, 1958, show no such radiation below 90 km. On the other hand, very strong correlations have recently been observed by L. G. Jacchia between solar events and atmospheric density at an altitude of 300 km. (See *Bulletin No. 32*).

It is planned to continue these simultaneous measurements of temperatures and winds up to the highest possible altitudes in future rocket measurements. Day-to-day synoptic measurements such as those carried out on a world-wide basis by radiosonde balloons are not believed necessary for the higher-altitude investigations. However, a set of "semi-synoptic" rocket flights at strategic locations (equatorial regions, middle latitudes, and several sites near and within the polar regions) will make possible a thorough insight into the relations between the upper atmosphere and the troposphere.

Unusual Solar-Terrestrial Event

The following report is based on material prepared by the National Bureau of Standards, relating to observations at its Boulder Laboratories by the solar research group of the Radio Warning Services Section.

An unusual solar event, completely at variance with the experience of many years, occurred on June 9, 1959, and has raised questions about the validity of what were considered established relationships between these events and terrestrial effects such as radio fadeouts and geomagnetic disturbances. (For a discussion of the terrestrial effects of flares and other solar activity, see *Bulletin No. 32*.)

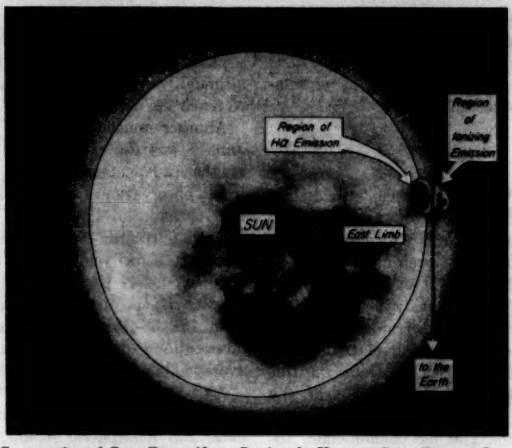

Fig. 4. *Cross-section of Sun, From Above, During the Unusual Solar Event of June 9, 1959.*

The investigation of the association between solar events, ionospheric disturbances, and geomagnetic storms has played an important part in the Bureau's radio propagation prediction services, particularly in the radio disturbance warning network. Part of this prediction work, based on the analysis and evaluation of solar radio data received from many sources, involves determination of the relationships between various solar events, radio fadeout, and temporary changes in the earth's magnetic field. The unusual solar event of June 9 does not fit the previous understanding of such associations, and is therefore considered an anomaly of major importance.

Description of Event

A severe radio blackout of very long duration, accompanied by large radio-noise outbursts on a number of wavelengths began at 1630 UT on June 9, 1959. No solar flare could be seen on the sun's disk, however, although a prominent flare would normally be visible at the same time as this type of radio disturbance is recorded.

As soon as the severity of the blackout became apparent, radio and optical observations were intensified. The initial position of the radio-burst source on the sun's disk was established, by high-resolution scan at a wave length of 10.7 centimeters (about 3000 megacycles), to be N 24, E 90, on the eastern edge of the disk. In the light of the hydrogen-alpha (Hα) spectral line, only jets (spikes emerging from the chromosphere) and bright loops (a rare type of gaseous prominence generated by large and active sunspot groups) were observed at this position. It was not until almost 1½ hours after the first event that the expected Hα flare became observable, at N 19, E 90. (See Figure 4.)

Complete blackout of the Bureau's radio station, WWV, occurred at a number of receiving locations. Cosmic-noise absorption of an outstanding nature (3 +) was evidenced by the great drop-off in received signal strength, and also by the unusually slow onset of the absorption. Solar radio bursts at relatively low frequencies (18 mc) were

classified as 3+ in importance, and bursts at high frequencies (about 3000 and 70,000 mc) were very strong. These observations classify the ionospheric events as of relatively great importance (3+).

Discussion

Past observations of such outstanding events have, in almost all cases, revealed the presence of an Hα flare of major importance. The absence of such a flare in itself established the June 9 event as a most unusual one. The anomaly also creates a number of problems concerning the understanding of solar-terrestrial relationship.

Both of the Hα jet ejections on this occasion appeared to be based near the sun's eastern limb on the side facing away from the earth. The jet phenomenon, together with the unusually late appearance of the flare itself, lead to the speculation that an early stage of the flare also occurred on the other side of the sun and in closer time-association with the earlier terrestrial events.

There is, of course, no way of establishing the actual occurrence of this unobserved flare on the other side of the sun as a fact. The assumption that there was such a flare presents still another problem: ascertaining how the solar radio emission and the ionizing emission that produced the radio fadeout could have reached the earth if they were generated in the same solar region as the unobserved Hα flare. Normally, both emissions—Hα and the ionizing radiation—travel in essentially straight lines. For these emissions to come from the same source, it would be necessary to assume a different trajectory for the Hα emission from the other side of the sun than for the ionizing radiation, a conclusion at variance with many prior observations. However, it may be inferred that the Hα flare originated at a lower level in the sun's atmosphere than the source of the emissions. This inference would help to explain why the Hα flare was not observed, although the ionizing radiation was able to reach the earth.

Another unusual feature of the event of June 9 was the exceptionally low velocity of the radio-emission source, as deduced from observations at two separate low frequencies. Slow-drift bursts on dynamic spectrum records (see *Bulletin No. 29*) normally show velocities of the order of 1000 kilometers per second at metric wave lengths. By comparison, velocities derived from 18-, 38-, and 200-mc fixed-frequency observations during the June 9 event average about 250 km/sec.

An additional unusual aspect of the event was the lack of subsequent major geomagnetic and ionospheric storms. The earth's magnetic field registered no major disturbances in the following few days, although there was a "sudden commencement" (the sudden onset of a magnetic disturbance) on June 11, followed by moderately disturbed three-hour K figures of 5, 6, and 5. Under ordinary circumstances, major disturbances would be expected. (The K-index expresses geomagnetic activity in terms of a scale ranging from 0, or very quiet, to 9, or extremely disturbed.)

Conclusions

The lack of geomagnetic and ionospheric disturbances in the solar event of June 9, coupled with the other apparent anomalies, has forced a critical reappraisal of past techniques of observation and of earlier conclusions from observational data. The resulting inquiry can be expected to lead to increased understanding of the relationships between the individual components of associated solar events and to a consequent improvement in radio-propagation prediction methods.

Nighttime Radio Propagation in Equatorial Regions

First Results of the IGY Amateur Radio Research Program

The following report is based on a more detailed account by Mason P. Southworth, project supervisor of the American Radio Relay League's IGY Propagation Research Project. The earlier report appeared in the Journal of Geophysical Research, *February 1960.*

During the IGY, thousands of reports by radio amateurs ("hams") of ionospheric propagation at frequencies of 50–54 megacycles per second and 144–148 mc/sec were collected by the ARRL, evaluated, and transcribed to punched cards for computer reduction and subsequent analysis. (*Bulletin No. 15* outlines the aims and organization of the Propagation Research Project and describes briefly the propagation "modes" investigated.)

In 1947, radio amateurs made the first 50-mc/sec contacts across the magnetic equator—between Mexico and Argentina. Since then, many similar very-high-frequency (VHF) contacts have shown that such "transequatorial-scatter" propagation can consistently be achieved during evening hours throughout sunspot maximum, when special conditions prevail in the equatorial ionosphere; it has also been shown that such transmissions fall off greatly, or cannot be effected at all, during the portion of the 11-year solar cycle when sunspot activity is at a minimum. (Radio signals at frequencies higher than about 30 mc/sec normally penetrate the ionosphere entirely and continue into space; under special conditions, however, generally by "scatter" from irregularities or discontinuities in ionization density, or by reflection from clouds or patches of unusually high ionization in the E-region—termed sporadic E—VHF signals up to about 100 mc/sec can be reflected back to earth.)

The ARRL-IGY Propagation Research Project was made possible by the hundreds of radio amateurs who contributed long hours of listening for 50-mc/sec signals. A large number of participants, in addition to spending many evenings at their sets waiting for transequatorial propagation to begin, remained late into the night in order to catch the very end. Moreover, several stations cooperated by transmitting continuous beacon signals. Negative reports—dates and times when 50-mc/sec transmissions were not received—were also made in order to give as complete a picture as possible of the record of transequatorial propagation.

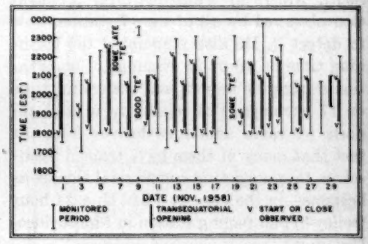

Fig. 5. *Monitoring Record for Amateur Station PZ1AE, Paramaribo, Surinam, November 1958. "TE" refers to transequatorial propagation.*

Typical of the PRP participants was amateur operator PZ1AE, of Paramaribo, Surinam. Figure 5 is a monitoring record

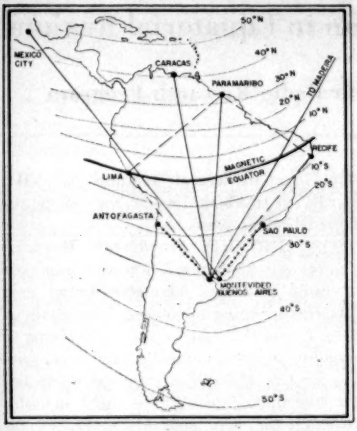

Fig. 6. *Typical Paths of 50-mc/sec Night-time Signals Observed by Radio Amateurs in South America. Solid lines are long-range, dashed lines medium-range, and small circles short-range paths.*

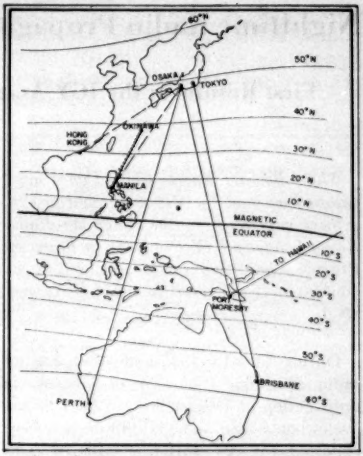

Fig. 7. *Typical Paths of 50-mc/sec Night-time Signals Observed by Radio Amateurs in the Far East. Paths as in Figure 6.*

for operator PZ1AE during November 1958. In this interval, PZ1AE reported all but three of the total number of instances of South American transequatorial propagation observed by all of the 17 stations able to detect it. He also pinpointed the beginning time on 20 of 21 evenings of observation during the month, and the ending time on 17 evenings. The reliability of such reports by radio amateurs derives from the fact that many of them have trained themselves to use existing commercial signals as beacons—in the case of PZ1AE, a 24-hour trolley-repair paging station in Montevideo, Uraguay.

Equatorial Propagation Paths

For convenience, the nocturnal 50-mc/sec propagation reported from South America, and more recently from the Far East, has been separated into three main categories on the basis of path length (see Figs. 6 and 7). The longest are the transequatorial paths, ranging from 4000 to nearly 9000 kilometers in length. These paths are roughly bisected by the magnetic equator and their end points generally have magnetic dip angles between 20° and 60°. Medium-range paths are from 2500 to 4000 km in length and paths between 200 and 2500 km long are in the short-range category.

Over long-range transequatorial paths, amateurs in the Buenos Aires-Montevideo area can contact Paramaribo, Caracas, and Mexico City (Fig. 6) almost nightly during the equinoctial months of each year. The Madeira Islands are heard only slightly less often. Stations in Paramaribo and the Buenos Aires-Montevideo region also receive medium-range signals from Lima and Recife, usually at the same time they are receiving long-range signals from each other and from other stations. Typical short-range paths are those linking Buenos Aires-Montevideo with Sao Paulo and An-

tofagasta. The distances traversed by these short-range paths resemble those of single-hop equatorial sporadic-E propagation (see *Bulletin Nos. 25, 29, and 33*); however, the short-range 50-mc/sec signals described in the present report are heard at the same times and with the same regularity as the longer-range transequatorial signals.

During the past few years, additional 50-mc/sec transequatorial data have also been obtained in other parts of the world. Australian amateurs first heard evening 50-mc/sec propagation from Japan in early 1957, and in the same year regular work was begun between southern Europe and southern Africa. Figure 7 shows typical Far Eastern paths for this mode of propagation. Observations by the National Bureau of Standards over the Phillipines-Okinawa circuit (see *Bulletin No. 26*) show the exact short-range characteristics that would be expected on the basis of the South American amateur results.

Daily Variations

The top five curves of Figure 8 show the daily characteristics in October 1958 of propagation over specific 50-mc/sec transequatorial circuits in the Western Hemisphere. The bottom curve shows the same thing for 40-mc/sec long-range echoes heard by B. Dueño at the University of Puerto Rico. The curves show the number of evenings that signals were received on each path in terms of local time at the mid-point of the path.

The 50-mc/sec curves show similar maxima at 2100-2200 hours, in good agreement with the mid-point time peak of 2130 hours reported by R. G. Cracknell for 50-mc/sec transmission between Southern Rhodesia and Cyprus. Results for the 40-mc/sec transequatorial echoes are markedly different, however. The 40-mc/sec signals faded out at Puerto Rico before the 50-mc/sec transmissions of Buenos Aires amateurs began to reach Puerto Rico. If the same mechanism accounts for both modes, it must be a very unusual one, especially since the 40-mc/sec echoes do not reappear later in the evening.

Data on 50-mc/sec transequatorial propagation in other parts of the world have been plotted in the same manner as the South American data. In these plots, a circuit from Argentina to Hawaii is the only one with a daily variation distinctly resembling that of the 40-mc/sec path described above. They may share causative mechanisms as well. A curve for an Australia to Hawaii path appears to represent standard 50-mc/sec transequatorial propagation. Curves for paths from Japan to various parts of Australia have two parts, representing flutter fading and steady signals. While flutter fading is almost always present in South American transequatorial

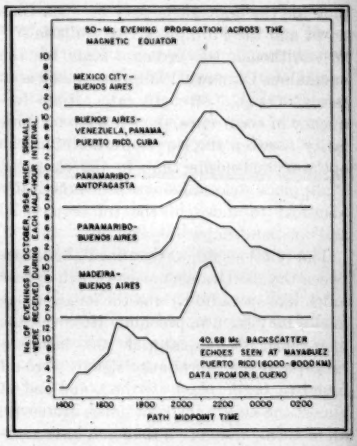
50-Mc EVENING PROPAGATION ACROSS THE MAGNETIC EQUATOR
MEXICO CITY – BUENOS AIRES
BUENOS AIRES – VENEZUELA, PANAMA, PUERTO RICO, CUBA
PARAMARIBO – ANTOFAGASTA
PARAMARIBO – BUENOS AIRES
MADEIRA – BUENOS AIRES
40.68 Mc BACKSCATTER ECHOES SEEN AT MAYAGUEZ PUERTO RICO (6000 - 8000 KM) DATA FROM DR B DUENO
NO. OF EVENINGS IN OCTOBER, 1958, WHEN SIGNALS WERE RECEIVED DURING EACH HALF-HOUR INTERVAL
1400 1600 1800 2000 2200 0000 0200
PATH MIDPOINT TIME

Fig. 8. *Daily Variations in Time of Occurrence of 50-mc/sec Transequatorial Propagation for Various Paths in and to South America, in October 1958. Curves for other parts of the world and for medium- and short-range equatorial propagation are essentially similar. A 40-mc/sec path is shown at the bottom for comparison.*

propagation, the Japanese and Australian paths have steady signals as well. The steady signals tend to appear first and may resemble the Puerto Rico backscatter signals. The fluttering signals seem similar in behavior to those over other transequatorial paths.

Daily variations over several medium-range paths, five circuits across South America and a sixth from Japan to Manila, have been similarly plotted. All of these circuits show about the same 2100- to 2200-hour maximum as the transequatorial paths. So does the curve drawn from Dueño's 40-mc/sec medium-range backscatter results, unlike the 40-mc/sec curve for long-range paths.

Daily plots of short-range propagation were drawn for a Buenos Aires-to-Antofagasta path during October 1957 and October 1958. These were compared with a plot for the anomalous path between Okinawa and the Phillipines (see *Bulletin No. 26*). Although the ordinate scale for the anomalous Okinawa-Philippines mode is in terms of signal strength rather than frequency of occurrence, there is a strong similarity between the curves. In addition, the optimum and closing times for the Okinawa-Philippines transmissions are practically identical to those of the transequatorial and medium-range propagation.

The relationship, as described above, between the short-range modes (which appear much like sporadic E) and the longer-range modes may seem improbable. However, the long-range transequatorial, the medium-range, and the short-range signals were all found to begin, reach maxima, and end at almost the same mid-point times. Moreover, all of them, more often than not, have similar fading characteristics and all are observed on the same evenings.

Because of the times of day these modes are operative, they seem less likely to involve ionospheric layer tilts than do transequatorial echoes heard at the Virgin Islands and Puerto Rico on lower frequencies. The 50-mc/sec amateur observations appear more closely connected in time with a patch of high electron density recently observed by D. M. Gates, of NBS, over Bogotá (magnetic dip angle 32°) at about 2200 hours. This patch, with a critical frequency of about 21 mc/sec, can account for a few circuits directly. If it were known whether such patches have also formed in the Far East and in South America south of the equator, as well as when and where they may have formed, some additional paths might perhaps be explained.

Seasonal Variations

In order to observe the variation patterns of equatorial modes throughout the year, plots of the number of nights per month on which transequatorial signals were received were made for the Americas and the Far East for the period January 1957 through July 1959 (see Fig. 9). Seasonal graphs for

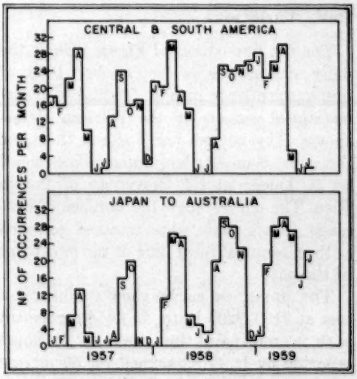

Fig. 9. *Seasonal Variations in the Frequency of Occurrence of Evening Transequatorial Propagation at 50 mc/sec.*

medium- and short-range propagation look much the same. (For about the first nine months of 1957, Australian amateurs were

not able to use the 50-mc/sec band. Hence, there were fewer transequatorial contacts than would otherwise have been made, and the curve representing this interval cannot, therefore, be accepted at face value.)

Past references to transequatorial propagation have mentioned maxima at the equinoxes and minima at the solstices. In the present data, however, it appears that the situation is not quite so simple. While the equinoctial months of March-April and September-October often have maxima, the solstice periods of December-January 1958 and 1959, in South America, have even higher maxima, and June and July 1959 in the Far East were not far below the equinox peak.

A critical look back over the data for the solstices shows that the November-through-February period is almost always higher in activity than May through August in the Americas, whereas the opposite is true for Australia-Japan paths. An obvious geophysical factor with which this difference between the Western Hemisphere and the Far East may be related is the change in relative position of the magnetic equator with change in longitude. On this side of the world the magnetic equator is south of the geographic equator, while in the Far East their positions are reversed (see *Bulletin No. 17*, Fig. 1). Perhaps the solstice when transequatorial scatter is likely to be high is the one that occurs when it is summer along the magnetic equator. H. W. Wells has reported the same relationship with respect to the equatorial spread-F mode of propagation during the period 1938–1954. Dueño's 40-mc/sec data for 1958 and 1959, on the other hand, do not reveal a solstitial preference.

Relationship to Geomagnetic Activity

Western Hemisphere transequatorial propagation at 50 mc/sec is compared with magnetic activity in Figure 10. The figure shows the interval during each evening

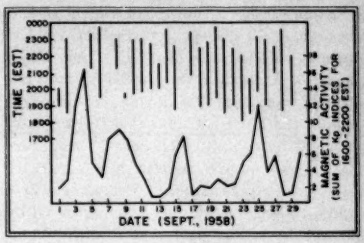

Fig. 10. *Comparison Between Times of Occurrence of Transequatorial Propagation and Geomagnetic Activity during September 1958. K, indices express intensity of geomagnetic activity on a scale ranging from 0 (very quiet) to 9 (extremely disturbed); in the graph above, two K, indices have been summed to obtain a figure for the hours 1600–2200 EST on each evening.*

(roughly in terms of average path midpoint time) when such propagation was observed somewhere in South America. The curve thus produced is compared with magnetic activity during the hours of 1600–2200 EST for each evening. September is one of the best months for transequatorial propagation; yet, almost everytime there was high magnetic activity, such propagation was either nonexistent or did not begin until the usual optimum hour was reached. When conditions were less favorable for transequatorial transmission, a very mild magnetic disturbance sufficed to eliminate the evening's 50-mc/sec contacts. Such an inverse correlation with magnetic activity is a well-known characteristic of equatorial spread-F propagation. However, long-range evening echoes at 40 mc/sec from Puerto Rico do not show this relationship.

Frequency and Fading Characteristics

The upper frequency limit of these equatorial modes is much above 50 mc/sec. Police signals from Cyprus at 70 to 72 mc/sec, for example, are received in the Rhodesias just about as often as are 50-mc/sec

amateur transmissions. Television signals as high as 72 mc/sec (channel 4) are frequently propagated from Caracas, Venezuela, to Argentina, and the NBS group has extrapolated that the anomalous propagation in the Far East (*Bulletin No. 26*) may be identifiable up to 80 or 90 mc/sec. These findings are quite consistent, moreover, with the fact that Brazilian TV channels 3, 4 and 5 (60–82 mc/sec) are often received by Argentine stations over similar paths. Thus, future investigations of these phenomena should probably be conducted in terms of frequencies above 50 mc/sec rather than the traditional lower ones.

Most long-range transequatorial signals, and very often those of medium and short range, have a characteristic rapid flutter fading, which seems to be on the order of 5 cycles per second. This fading is usually very deep and capable of modulating a strong signal completely into the noise level. Little more is known about this phenomenon as yet, but an amateur recording program has been set up that should yield records suitable for more detailed analysis.

Conclusions

Transequatorial scatter propagation of radio signals, as observed by amateurs at 50–75 mc/sec, is intimately connected with medium-range propagation to the neighborhood of the magnetic equator and also with short-range transmission for distances beyond a few hundred kilometers. All of these categories occur most frequently at path mid-point times of 2100–2200 hours, are most pronounced around the equinoxes, and have similar fading characteristics.

These 50-mc/sec echoes are probably not related to the long-range echoes heard on lower frequencies at the Virgin Islands and Puerto Rico, where ionospheric layer tilts are believed to be the cause. Although the amateur 50-mc/sec results do show a daily variation similar to that of the 40-mc/sec medium-range echoes at Puerto Rico, the amateur equipments are considerably more sensitive than the Puerto Rico backscatter sounder, and different mechanisms may therefore still be involved. One such mechanism might be the patch of high electron density that has appeared at 2200 hours in the true-height profiles constructed for the NBS chain of stations along the 75°W meridian (see *Bulletin No. 29*). The transequatorial scatter observed at 50 mc/sec also has some of the same general characteristics (daily and seasonal variation and relation to geomagnetic activity) as equatorial spread F.

International Rocket Intervals

In order to obtain solar, geophysical, and meteorological data simultaneously in a number of widely separated regions of the world, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) is sponsoring a series of International Rocket Intervals.

The first rocket interval took place November 16–22, 1959, and was part of the IGC-59 program, successor to the IGY. The second interval, September 16–22, 1960, was designated by COSPAR to coincide with part of the World Meteorological Interval (WMI) planned for this period in accordance with the International Geophysical Calendar 1960 (see *Bulletin No. 30*). (WMI are characterized by a general, world-wide intensification of meteorological, solar, and

geophysical observations.) The Space Science Board (SSB) of the National Academy of Sciences coordinated US participation in the first two International Rocket Intervals.

COSPAR has scheduled two major International Rocket Intervals for 1961. The first, from February 12 to 18, will be concerned primarily with solar-terrestrial effects related to the total solar eclipse expected on February 15, and with winter atmospheric structure in the Northern Hemisphere. Launchings during the second major interval of 1961, July 16–25, will emphasize atmospheric structure during the Northern Hemisphere summer. Rocket flights designed for solar and upper-atmosphere observations will also be made during the seasonal meteorological rocket intervals (see below) scheduled for January, April, and October 1961.

September 1960 Rocket Interval: Approximately 27 research rockets were launched as part of the US contribution to the September 16–22 interval, 22 of them for meteorological measurements and the remainder for other geophysical investigations. Scheduled for geophysical flights were a National Aeronautics and Space Administration experiment using nuclear emulsions to investigate the lower portions of the Van Allen radiation region; Air Force Geophysics Research Directorate experiments dealing with atmospheric composition and density; and Army Ballistic Research Laboratories rocket and balloon flights carrying water-vapor experiments and frost-point hygrometers. Results of these experiments, as well as of the meteorological flights, will be reported by the SSB to COSPAR for distribution to the world scientific community, and will also be deposited in the IGY World Data Centers.

Meteorological Flights: For more than 20 years, weather balloons launched two or more times daily from an increasingly dense network of stations throughout the world have provided data on pressure, temperature, humidity, and winds up to an altitude of about 100,000 feet (about 20 miles). The development of small, relatively inexpensive scientific rockets during the past few years now makes it possible to extend this synoptic weather-balloon technique to altitudes two or more times as great through simultaneous launchings from a number of widely separated points.

During the September 1960 interval, temperatures and air densities were measured each day by Arcas and Loki rockets launched from sites in Florida, California, Nevada, Virginia, and New Mexico. These meteorological sounding rockets covered an altitude range of 75,000 to 200,000 feet (about 15–40 miles); however, one Arcas rocket reached an altitude of 264,500 feet above White Sands, New Mexico, the greatest height ever achieved by this type of rocket.

The sites of these launchings constitute a meteorological rocket network established to gather synoptic meteorological data on a nationwide basis for month-long periods in the winter, spring, summer, and autumn. The flights made by this network are part of the US contribution to the International Rocket Intervals.

NASA Nuclear Emulsion Experiment: The NASA Nuclear Emulsion Recovery Vehicle ("NERV") was designed to measure radiation in the Van Allen region (see *Bulletin No. 30*) and return the recorded data to earth for study. The four-stage, solid-propellant Argo D-8 rocket, was launched southwestward from Point Arguello, California, on September 19, 1960. It sent an 83-pound payload to an altitude of about 1200 miles and for a distance of approximately 1200 miles down range, as planned. The payload was parachuted to the sea surface and recovered by US Navy vessels stationed in the impact area.

The stack of nuclear emulsions carried by the vehicle was designed to record the passage of all charged particles with energies of 5,000,000 electron volts or greater, thus providing a profile through the geo-

magnetically trapped radiation in this geographic region. The emulsions were exposed to radiation from an altitude of about 300 statute miles on the up leg of the flight, through apogee, and down to a height of about 600 miles.

In this geographic area, the innermost of the two Van Allen belts of high-intensity radiation within the vast atmospheric region of geomagnetic trapping dips to within approximately 700 miles of the Earth's surface. Hence, the radiation profile includes a substantial portion of this inner high-intensity belt. The NERV flight also carried a related biological experiment using mold spores, and a micrometeorite experiment.

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Gravity Measurements on a Surface Ship at Sea

The following material is based on a more detailed report by J. L. Worzel, of the Lamont Geological Observatory, Columbia University. The earlier report appeared in the Journal of Geophysical Research, *September 1959.*

The restless nature of the sea has in the past made it extremely difficult to obtain measurements of the Earth's gravity over the 80% of its area covered by water, since such measurements must be made from a stable surface. Previously, it was possible to make only a relatively small number of oceanic observations from submarines resting at quite depths. However, with the development a few years ago, by Anton Graf of Munich, Germany, of a new submarine gravimeter that J. L. Worzel was able to adapt for use on a stabilized platform aboard a surface ship, gravity measurements can now be made successfully at sea anywhere in the world.

A detailed description of the instrument, operational procedures, and computation and correction methods is given in the *JGR* report mentioned above, and an account of the first marine test of the Graf Sea Gravimeter appears in *Bulletin No. 8.* The present report reviews the results of further sea-surface experiments made aboard the *USS Compass Island,* an 18,000-ton US Navy vessel fitted with a stabilized platform. The cruise, conducted during a five-week period in March and April 1958, covered portions of the North Atlantic and Mediterranean Sea (see Fig. 1).

Captain L. L. Schock of the Navy's Bureau of Ordnance made arrangements for the test series, and the officers and crew

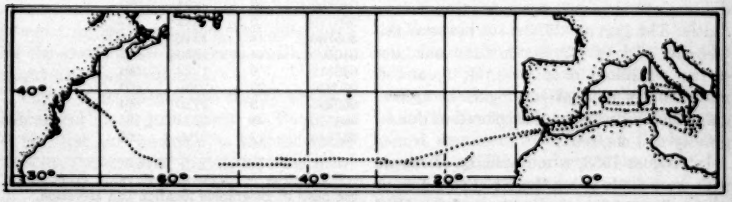

Fig. 1. *Portions of the Cruise Track of* USS Compass Island *in the Atlantic Ocean and Mediterranean Sea, in March–April 1958, Along Which Gravity Measurements Were Made.*

of the *Compass Island*, under the command of Captain J. A. Dare, gave very important assistance. V. R. Sinclair, J. G. Gallagher, and G. Pritchard participated in the observation program, which was directed by J. L. Worzel, and Annette E. Trefzer assisted with computations and drafting of figures. Important advice and encouragement were received from Maurice Ewing and Merle Tuve. The project was sponsored by the US National Committee for the IGY, of the National Academy of Sciences, and supported by a National Science Foundation grant.

Cruise Measurements

Calibration measurements based on comparisons with measurements made by a Frost gravimeter show that the Graf Sea Gravimeter measures gravity satisfactorily on land; that the meter also makes satisfactory measurements on a submerged submarine was shown by Worzel and Graf in 1957; and comparisons with previous observations made at various base stations (the New York Naval Shipyard, the Naples area, Italy, and at two locations in the harbor at Palma, Majorca, in the Western Mediterranean) show that the meter gives satisfactory results on a surface ship in harbors. The observations reviewed in the present report demonstrate that gravity measurements can now be made successfully on a surface ship at sea.

One of the early cruises of the *Compass Island* crossed three profiles of gravity data previously made with Vening Meinesz pendulums off the east coast of the United States. The gravity differences between the *Compass Island* measurements and the earlier pendulum data were 11, 6, and 6 milligals. (A milligal—or mgal—is 1/1000 gal, which represents an acceleration due to gravity of 1 cm/sec^2.)

In August 1958, a multiplicity of repeat runs were made along the New York line of submarine gravity observations of the *USS Tusk* in 1947 and duplicated in 1957 by the *Compass Island* in the first oceanic test of the Graf gravimeter (see *Bulletin No. 8*). One of these runs was the only one on which it was possible to make simultaneous observations with two instruments mounted on the same stable platform.

The maximum spread of the observations for the different runs with one meter is 20 mgal. The difference between the two meters recording simultaneously on a single run was essentially zero. The 20 mgal spread must, therefore, be attributed to the fact that the runs were not made over identical courses and to a lack of precise knowledge of the speed over the "ground," needed for computing the Eötvös correction (correction applied to observed gravity values to account for the effects of changes in the ship's centrifugal acceleration owing to the rotation of the Earth; these changes depend primarily on the east-west component of the ship's motion). The agreement with

Table 1—Comparison of Gravity Observations at Crossings of the Ship's Own Track

Date and Time	Anomaly* (mgal)	Depth (meters)	Course (degrees)	Approximate Difference** (mgal)
250515	−17	2006	091	
300815	−21	2001	312	4
300830	−17	1869	312	
291145	34	572	181	
291200	37	572	183	
040745	28	539	091	11
040800	24	587	091	
292115	20	732	001	
040630	23	662	091	0
040645	12	977	091	
300600	18	1158	196	
300615	21	839	196	0
040545	22	894	091	
300715	6	1324	312	
300730	−4	1516	312	
040500	4	1350	093	3
040515	9	1723	091	
060930	−29	2359	091	
060945	−18	2110	091	
061730	−8	2332	295	1
061745	−17	2109	295	

* Variation from theoretical value expected on the basis of geographic location and elevation.

** "Approximate" because of navigational uncertainties.

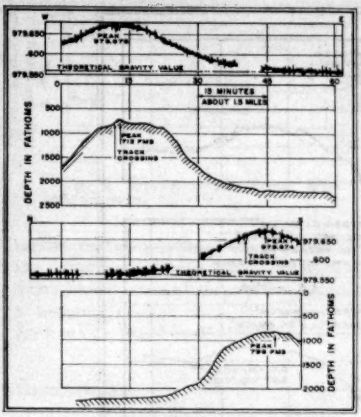

Fig. 2. *Gravity Profiles and Bottom Topography Along N-S and E-W Crossings of a Seamount Just North of Bermuda.*

previously made pendulum observations is as good as could be expected if the navigational errors of the two sets of observations and the differences of positions are considered.

Table 1 shows gravity variations for six crossings by the *Compass Island* of its own track in the Mediterranean when cruising on different courses. The navigation along these tracks was by celestial observations, radar fixes on shore as opportunity permitted, and dead reckoning. The approximate gravity differences were obtained by interpolation to the indicated crossing point between the values computed regularly at 15-minute intervals. These differences are referred to as approximate because of the uncertainties inherent in the navigation. The differences for the crossings are thus even smaller than might have been expected.

Figure 2 represents two tracks across a submerged peak just north of Bermuda. (The "free-air" anomaly is the difference between the observed gravity and the theoretical gravity given by the International Formula of Gravity.) Two crossings were also made of Caryn Peak, a much smaller feature beyond the mouth of the Hudson Submarine Canyon, which cuts the sea bottom on the continental shelf for more than 200 miles southeastward from the mouth of the Hudson River. The gravity signature is much smaller than for the peak north of Bermuda but it is still quite definite.

A west-to-east track across Cruiser Seamount, several hundred miles south of the Azores, is represented in Figure 3. The figure also shows seismic refraction measurements made on the seamount as well as seismic observations made on a previous cruise in locations similar to the flanks of the seamount but about 100 miles to the north. These gravity and seismic data, along with seismic-velocity and rock-density information compiled by J. E. Nafe and C. L. Drake, have permitted M. Talwani, of Lamont, to compute the shape of the Mohorovičić discontinuity (interface between the Earth's crust and the denser mantle directly beneath it) in the vicinity of the Cruiser Seamount. Although Talwani represented the seamount as a two-dimensional structure in these calculations, only minor changes would be required (probably less than a two-kilometer change in position of the M-discontinuity) in recomputations on the basis of a three-dimensional structure. Nevertheless, this diagram is substantially correct. It is interesting to note that it took only one day to observe and compute the gravity and two days to plot and compute the section.

Two crossings of the Tyrrhenian Sea were also profiled, and previously observed submarine gravity points within five miles of the *Compass Island's* track were plotted for comparison. The agreement between the two tracks is generally satisfactory.

Figure 4 shows a section across the Canary Basin. To the right, the track crossed an unnamed seamount and Ampere Bank. One previous pendulum observation made by Vening Meinesz, near the center of the section, shows excellent agreement. It is obvious that such a profile provides a much

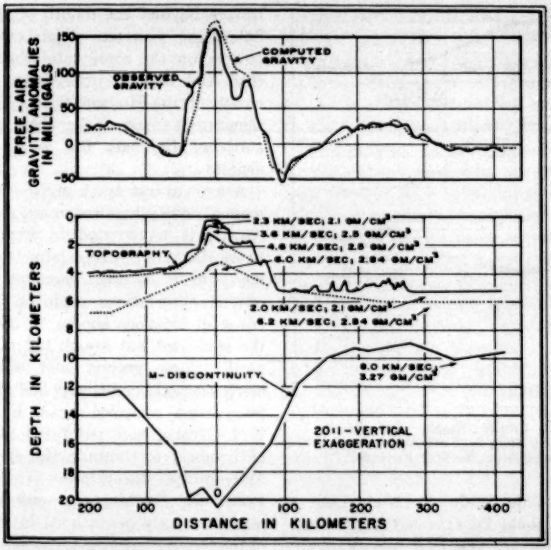

Fig. 3. *Gravity Profile of W-E Crossing of Cruiser Seamount, South of the Azores. Bottom Topography, seismic velocities in the crust and mantle, and configuration of Mohorovičić Discontinuity shown in lower portion of chart.*

better basis for picking a representative value of gravity for an area than is provided by observations at specific points. The roughness of the gravity curve indicates that topography similar to that of the Mid-Atlantic Ridge to the west and of the Continental Rise to the east must be buried beneath the Madeira Abyssal Plain.

A section across the Mid-Atlantic Ridge is shown in Figure 5. Again, it is obvious that a much more representative gravity

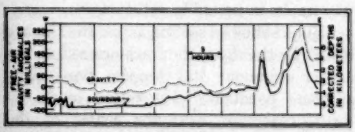

Fig. 4. *Canary Basin Gravity Profile. Unnamed seamount and Ampere Bank at right.*

anomaly value for an area can be determined from such a continuous curve than from individual points.

Figure 6 shows the results of two passages, never less than five miles apart, through the Strait of Gibraltar. The most obvious feature is the double negative anomaly, of the order of 100 mgal, shown by arrows on the chart. The agreement between the two passages is very impressive.

Since the cruise tracks were separated by at least five miles, it is obvious that the trend of the negative anomalies is almost north-south. It is important to point out that the existence of this double negative would probably never have become known from submarine gravity measurements because ship traffic is so dense in this region that it is almost impossible to make a submerged run of sufficient duration without

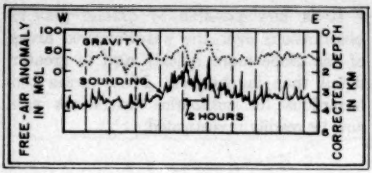

Fig. 5. *Gravity Profile Across Mid-Atlantic Ridge.*

serious risk of collision. It is probable that the eastern negative is associated with the Atlas Mountains and the western one with a former Paleozoic mountain system, according to a study by H. D. Klemme.

Conclusions

On a five-week cruise to the Mediterranean Sea aboard the *USS Compass Island* in March and April of 1958, it was possible to make gravity measurements 70% of the time. Observations were made 50% of the time in the Mediterranean. Since the limiting factor was the vessel's vertical heave, this record could have been greatly improved if the ship's course had been chosen for the benefit of gravity observations. Vertical heave is minimized when heading into the swells and maximized when heading across the swells.

The observations described above indicate that continuous gravity measurements can be made at sea with a precision of ±5 mgal using the Graf Sea Gravimeter mounted on a stable platform on a surface vessel. Some uncertainties arise, principally from the Eötvös effect and from the difficulty of determining the ship's precise location. When it becomes possible to determine a ship's position and speed over the bottom more accurately, the precision of the measurements should improve considerably.

The continuous curves produced by this technique greatly enhance the value of gravity observations at sea. They permit more representative gravity values, as are required for many geodetic studies, to be chosen for ocean areas. The interpretation of gravity anomalies depends almost entirely on the shape of the observed curve. Thus, a continuous curve is obviously much better for this purpose than a curve drawn to fit a number of discrete points. Continuous curves reduce the chance of errors in calculation that are always present in computations based on discrete observations. Continuous observations also prevent the overlooking of new features whose existence was not anticipated.

It remains to be seen whether the Graf Sea Gravimeter can be used successfully on smaller, unstabilized vessels. A stable platform and a Graf Sea Gravimeter have been installed on the Lamont Geological Observatory's 500-ton, 200-foot research vessel *Vema*. It was expected that observations from such a vessel could be made for a smaller fraction of time, however, because a small vessel would be more readily

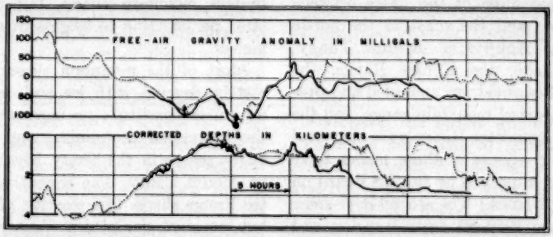

Fig. 6. *Two Gravity Profiles Through Strait of Gibraltar. Arrows indicate minima in the gravity anomaly waves.*

and more completely affected by swells than would a larger vessel. (Since publication of the September 1959 *JGR* report on which the present material is based, Lamont investigators aboard the *Vema* have completed a 560-mile gravity profile.)

It is now possible to extend gravity observations over the water-covered areas of the globe more quickly and in greater detail than in the past. Many areas too hazardous for submarine operations can now be readily investigated.

Geological Observations in West Antarctica During Recent Oversnow Traverses

The following material is based on a report by George A. Doumani of the Institute of Polar Studies, Ohio State University. Mr. Doumani participated in seismologic and glaciologic studies at Byrd Station, and was a member of the two oversnow traverses discussed below, during 1959 and early 1960.

General geological investigations were conducted at accessible rock exposures in Marie Byrd Land west and north of Byrd Station during two major oversnow traverses in 1959 and 1960. The first, an IGC-59 traverse to the Executive Committee Range, was made in the austral autumn of 1959. The observations were made mainly at Mount Sidley, highest and most prominent feature of the Executive Committee Range. (See Figure 7.)

The following spring, a reconnaissance flight covered most of the areas between Byrd Station and the coast to the north. The Crary Mountains, Mount Toney, Mount Takahe, the Kohler Range, the Amundsen Sea coast, an unnamed and previously uncharted mountain range, and the Executive Committee Range were inspected from the air. (Some of these names have not yet been approved by the US Board on Geographic Names.) The second over-snow party, in the 1959–60 austral spring and summer, followed a similar route. Rock specimens were collected from most of these areas, from Mount Petras, and from the Clark Mountains of the Edsel Ford Ranges.

This report summarizes the geological information gathered on these expeditions. More detailed reports on specific areas are in preparation. Major geologic and geographic features of the regions visited are outlined in Table 2.

Coordination and administration of the United States Antarctic Research Program since the termination of the IGY has been the responsibility of the National Research Foundation. See *Bulletin No. 39* for information on the status of the over-all Antarctic Program.

General Physiographic Description

The mountains in the western part of Marie Byrd Land exhibit certain physiographic consistencies. They are not continuous mountain chains, but rather isolated peaks rising to heights of about 4200 meters.

Most of the mountain slopes are completely covered with ice and snow. Rock exposures constitute no more than 5% of the individual mountains, and are especially scarce in the Crary Mountains and on Mount Toney. The Executive Committee Range shares this scarcity of exposures but morainal glacial deposits are abundant on the ice surface where valley glaciers merge to form piedmont glaciers. In the northern coastal ranges, on the other hand

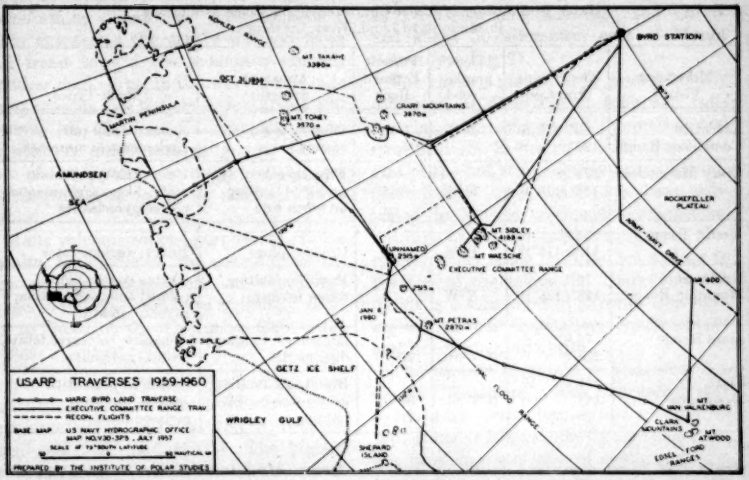

Fig. 7. Traverse Routes in Region North of Byrd Station, Antarctica. Elevations in meters above sea level.

—the Hal Flood and Edsel Ford ranges, and Mount Petras—whole mountains are commonly well exposed, and geological investigation is relatively easy.

Geologic Summaries for Regions Visited

Executive Committee Range: Four major mountains form the Executive Committee Range. Although these mountains are apparently connected with each other above sea level, ice covers the connecting areas as well as a great portion of the mountains themselves. The range trends generally north-south along longitude 126°W and between latitudes 76.5° and 77.2°S.

Most prominent of the four mountains of the range is Mount Sidley, an extinct volcano whose crater has developed into a cirque—a steep-sided, bowl-shaped recess commonly found at the head of a mountain glacier. The cirque walls rise about 1500 meters to the highest peak, which reaches an elevation of 4200 meters. The volcanic nature of Mount Sidley also characterizes the remainder of the range.

The south-eastern slope of the Executive Committee Range exhibits a conspicuous stratigraphic sequence of five tentatively-classified rock units. The lowermost unit is olivine basalt—a dark, extrusive igneous rock rich in the iron-magnesium silicate, olivine. At an elevation of about 2000 meters, the basalt surface displays sharp, symmetrical grooves, 10–15 centimeters in depth, apparently the result of abrasion by rock fragments imbedded in slowly flowing glacier ice.

Overlying the basalt are three distinct rock units consisting of compacted, fine-grained volcanic fragments, or tuff. They are red, yellow, and gray, in ascending order, and the lowest of the sequence lies unconformably upon the basalt. (An "unconformity" is a break in the depositional sequence of the rock strata in which younger

Table 2—Summary of Major Characteristics of Some Mountains in Marie Byrd Land, West Antarctica

Mountains Visited	Geographic Location	Geographic Trend	Percent Exposed Rock	Apparent Structure	Rock Types
Executive Committee Range	76°–77° S 126° W	N–S	<5	Dipping gently SE; craters	Basalt; lapilli tuff; agglomerates; moraines
Crary Mountains	76.9° S 116°–118°W	E–W	<5	Dipping gently SE; probable faulting on north side	Basalt (aa-type) flows; mafic dikes; agglomerates; coarse pyroclastics
Mount Toney	75.7° S 115°–116°W	E–W	<5	Craters; plugs	Basalt; agglomerates
Unnamed Mountain Range	76° S 123°–125°W	E–W	<5	Probable faulting; minor folding	Olivine basalt; light-colored tuff; tuff-breccia; rhyolite; diorite
Ames Range	75.8° S 128.2° W	NW–SE	20–25	High-angle faulting; dipping SE	Aphanitic to coarse felsite, probably rhyolite
Clark Mountains	77.3° S 142° W	NW–SE	90–95	High-angle faulting; gently dipping SE; jointing	Aplitic to pegmatitic granite; diorite; metasediments

strata rest upon a surface resulting from earlier erosion of the underlying older rocks.) These units are characterized by strong fragmentation and an abundance of accretionary lapilli—volcanic pellets, commonly with concentric structure. Cross-bedding, intercalation of strata, and partial rounding of the volcanic fragments characterize the gray tuff, which thus resembles a river deposit.

Glacial moraines are the uppermost deposits in the Mount Sidley rock sequence. Huge boulders of varying composition lie in a spectacular array of concentric arcuate patterns indicating stages of recession of the glacier ice. Large, well-developed crystals of anorthoclase feldspar found embedded in a boulder of reddish, vesicular lava are being used at present for age determinations by the potassium-argon radioisotope technique. Numerous boulders are strewn as far as 25 kilometers south of Mount Sidley, forming no apparent pattern. Their presence at such distances and their mode of occurrence raise questions concerning the mechanism by which they were carried to their present locations and deposited.

Crary Mountains: This range also consists of four main mountains; three have very prominent peaks, the highest attaining an elevation of more than 3700 meters. The mountains extend roughly east-west along 76.9°S and between 116° and 118°W.

The south side of the range slopes gently southward, meeting the ice cap in a relatively smooth incline. Ice covers more than 95% of the slopes of the range, but the few accessible outcrops permitted some geological investigation. The dominant rock type is a dark, extremely fine-grained basaltic lava containing larger almond-shaped crystals of feldspar similar to the anorthoclase from Mount Sidley (above). Highly contorted lava "bombs," evidence of explosive eruptive activity, occur both where they fell and as glacier-transported "erratics."

The north side of the range is steeper than the south side, and the ice cascading down the northern slopes is heavily crevassed. A well-exposed bedrock outcrop exhibits a succession of highly weathered lava flows, with characteristic caterpillar configuration. Clinkers similar to Hawaiian aa-type lava (rough, jagged, spiny basaltic lava) are clearly displayed. Two small

mafic (composed primarily of magnesian rock-forming silicates, or "dark minerals") dikes cut across the gently inclined flows and trend toward the mountain summit. Another mafic dike, to the west of this outcrop, extends up the slope for about 300 meters. All of these dikes appear to be vertical. A deep, vertical groove on the face of the northern outcrop, probably cut by running water, suggests seasonal thawing.

Mafic volcanic rocks—porphyritic olivine basalts, agglomerates, and coarse pyroclastics—appear characteristic of the entire range. Hand specimens are strikingly similar to those of the Executive Committee Range.

Mount Toney: Mount Toney is an elongate topographic feature trending roughly east-west along latitude 75.7°S between longitudes 115° and 116°W. The highest peak, apparently on the rim of an ancient volcanic crater, attains an elevation of approximately 3700 meters. The altitude of the main ridge decreases gradually from east to west and, as in the Crary Mountains, the southern slopes are gentle while the northern slopes are precipitous. Seismic soundings on the traverse showed that the bedrock surface beneath the ice between the Crary Mountains and Mount Toney is below sea level.

The only bedrock exposures on Mount Toney are on the northern slopes and constitute not more than 1% of the surface area. Examination of these exposures suggests that volcanics and agglomerates probably make up the major portion of the mountain. A mafic outcrop (of lamprophyric composition) occurs on the northeastern side of Mount Toney. This outcrop resembles a volcanic plug—solidified material filling the vent or pipe of a dead volcano. A circular, crater-like outcrop was seen from the air near the northeastern edge of the mountain.

Unnamed Mountain Range: This range consists of two major mountains and a low ridge, extending east-west along latitude 76°S between longitude 123° and 125°W and about 50 kilometers east of Mount Petras (see Fig. 7).

The eastern mountain is predominantly composed of light-colored tuffs and tuff-breccias, with conspicuous lamination and stratification. Brownish basalt crops out east of the tuff and probably overlies it unconformably. This basalt has been subjected to intense mechanical weathering, resulting in stepped, tombstone-shaped pinnacles, which occur from the ice surface to the top of the mountain. Underlying the basalt is a thin layer of rhyolite (the fine-grained to microcrystalline equivalent of granite) containing pyrite.

The western mountain is composed of a diorite "basement" rock unconformably overlain by olivine basalt, and a yellowish tuff. (Diorite is a granite-like igneous rock, but consists essentially of sodium-calcium feldspars with little or no quartz and potassium feldspar, while granite consists essentially of potassium feldspar and quartz.) The northern slope is covered with basaltic rock debris containing abundant inclusions of olivine, and other individual crystals, reaching five centimeters in length.

Mount Petras: From the air, the west side of Mount Petras appears to have the shape of a crater open to the north and occupied by a cirque glacier. Block-faulting apparently exists, with high-angle faults trending perpendicular to the mountain ridge, as indicated by zones of fault breccia and abundant striated, polished rock surfaces characteristic of fault planes.

Almost 25% of Mount Petras is exposed rock. The dominant rock type is a very fine-grained to coarse, granular rock, probably rhyolite, with large individual crystals in places. Pyrite is disseminated sparsely and randomly in a rhyolitic outcrop that is strikingly similar to the rhyolite found on the eastern mountain of the unnamed range (above).

Mountains and isolated peaks protrude

through the ice over a wide area. Pink granite intrudes a sequence of dark, well-stratified, partly metamorphased sedimentary rocks (metasediments). The granite contains large crystals of feldspar and ranges in texture from fine to very coarse grained. At Mount Van Valkenburg, the granite is intruded by two steep dikes of diorite; the "contact" area between the granite and the dike rock contains oval-shaped crystals of pink orthoclase feldspar and components of both granite and diorite.

At Mount Atwood, faults and joints in the granite are very conspicuous. A probable zone of faulting and brecciation, cleared of fine rock debris by very high winds, apparently created the split effect that gives the mountain two distinct peaks. The granite cliff walls contain well-rounded hollows, the result of wind abrasion with weathered granite crystals serving as the wind-carried abrasive.

The metasedimentary rocks overlying the granite are not greatly contorted by metamorphism, although some of the original sedimentary characteristics have been almost completely obliterated. The strata are intruded in many places by veinlets of quartz and fine-grained granite. Contact zones contain abundant mica, pyrite, and copper stains (malachite).

At Mount Van Valkenburg, the topography is controlled by the geologic structure. The saddle between the two peaks is in the plane of a high-angle, normal fault, which exhibits slickensides and brecciation.

Summary and Conclusions

Geological observations made thus far in West Antarctica indicate that the mountains visited (with the exception of the Clark Mountains) form an archipelago of isolated, volcanic "islands," trending generally east-west and possessing geologic and physiographic similarities. Further study of the rocks in this portion of Antarctica will help to determine its relationship to the remainder of Antarctica and to neighboring continents. Continued investigation is necessitated, moreover, by the failure thus far to observe major, broad-scale structural features in West Antarctica that can be correlated with features of neighboring and surrounding parts of the globe.

The NERV Experiment

The following report is based on material supplied by the National Aeronautics and Space Administration (NASA).

The NASA Nuclear Emulsion Recovery Vehicle (NERV) experiment was launched at 11:35 am EDT, September 19, 1960, from Point Arguello, California, as part of the United States contribution to the second International Rocket Interval (see *Bulletin No. 40*). The experiment was primarily designed to obtain detailed radiation measurements through part of the inner Van Allen belt of charged particles trapped in the Earth's magnetic field, and to return the information for study. NERV also carried a related biological experiment using mold spores.

The experimental vehicle, propelled by a newly designed Argo D-8 sounding rocket, reached an altitude of approximately 1200 miles and travelled 1200 miles downrange,

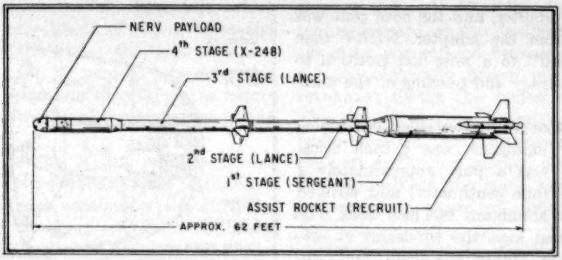

Fig. 8. *Argo D-8 Sounding Rocket Used in NERV Experiment.* (From NASA photograph.)

where it was recovered 2½ hours after launch by the *USS Rowan*, one of several US Navy vessels stationed in the impact area. This was the first flight of the Argo D-8 and, therefore, served also as a test of the new four-stage sounding rocket.

The NERV project is under the direction of NASA, with management responsibility assigned to NASA's Goddard Space Flight Center. Goddard conducted the emulsion experiment, and the mold-spore experiment was conducted by Florida State University. NERV was launched by the US Navy and was the first NASA rocket experiment flown from the West Coast. The Navy was also responsible for tracking and recovery operations.

Launch Vehicle

Aerolab Development Corporation (Pasadena, California), a subsidiary of the Ryan Aeronautical Company, manufactured the four-stage Argo D-8 launch vehicle (Fig. 8). The first stage, developed by the Thiokol Chemical Corporation, was a Sergeant rocket, which was assisted in the launch by two Recruit rockets attached to its sides. The second and third stages were Lance rockets developed by the Grand Central Rocket Company, and the fourth stage, an X-248 rocket, modified from the Vanguard final stage, was produced by the Allegany Ballistics Laboratories, a division of Hercules Powder Company.

Over-all length of the Argo D-8 was approximately 62 feet and its total weight was over 13,000 pounds. The unguided, solid-propellant launch vehicle gave the fourth stage a burnout velocity of more than 12,000 mph at an altitude of 124 miles, reached 95 seconds after liftoff. The fins of the first three stages were canted slightly, causing the stages to spin at 600 revolutions per minute during powered flight, thus providing spin stabilization for the fourth stage and payload.

NERV Payload

The complete NERV payload had an over-all length of 42 inches and a diameter of 19 inches. The payload was composed of two sections, the recovery vehicle and an adapter section that mated it to the fourth stage of the launch vehicle (see Fig. 9). The recovery vehicle was 16 inches long and was made of aluminum with an ablation heat shield. Including the experimental equipment, the vehicle weighed 83.6 pounds.

In addition to the experiments, NERV contained a programmer, two small electric motors, a battery supply, a parachute, and recovery aids such as radar chaff, a radio beacon, and a flashing light.

NERV was designed for aerodynamic stability during its re-entry into the atmosphere and drop into the sea. Just prior to re-entry, the payload was de-spun to 40 rpm by two weights attached to lines wound

around the adapter, and the nose cone was separated from the adapter. NERV then "righted itself" to a nose-first position to facilitate re-entry and opening of the parachute.

The cylindrical tungsten shield containing the nuclear emulsions was ⅛ inch thick. In its side was a port approximately ⅜ inch square (one centimeter) and covered by a layer of aluminum .004 inch thick. The aluminum seal kept the emulsions at sea-level pressure during the flight and prevented their exposure to sea water during recovery. The emulsion container section was 4¼ inches in diameter and, including a motor section (see below), 12½ inches long. The emulsion stack was approximately ½ inch long and 3 inches in diameter.

At an altitude of 300 statute miles on the upward leg of the NERV flight, the programmer activated a small electric motor which extended the shield 3½ inches forward, exposing the emulsions to radiation (Fig. 9). They remained exposed through the crest of the trajectory and down to a height of 600 miles on the descent, where they were retracted for re-entry. Another motor rotated the emulsions while they were extended.

The three packages of neurospora for the biological experiment had a total weight of .18 pound. Pieces of foam weighing a total of 1.5 pounds were put into NERV to give it buoyancy in the water should seepage occur.

Approximately 10 seconds after the parachute opened, the flashing light and recovery beacon were activated. Both beacon and light had a planned lifetime of approximately 30 hours, to improve chances of recovery.

At water impact, about 37 minutes after liftoff, a block of fluorescein dye was released. A second block of dye was contained in water-soluble tape designed to deteriorate from interaction with sea water in about 4 hours, releasing more dye and thus giving the dye markers a total lifetime of approximately 12 hours. However, the vehicle was retrieved after only about 2½ hours in the water.

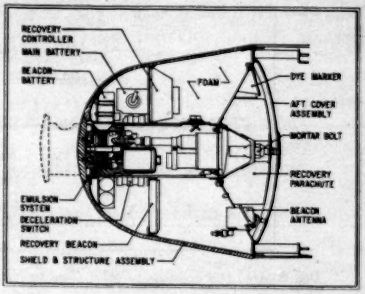

Fig. 9. *Cross section of NERV Payload. Dashed line at left indicates extended position of nuclear emulsion stacks. (From NASA photograph.)*

Emulsion Experiment

The NERV project is part of NASA's continuing program to investigate the nature, characteristics, history, and sources of the Van Allen radiation region. Studies based on data accumulated by the early Explorer satellites in 1958, conducted by James A. Van Allen and his colleagues at the State University of Iowa, revealed the presence of a region of high-intensity radiation trapped in the Earth's magnetic field. Subsequent studies, in particular those using the Pioneer space probes, provided further information about the extent, structure, composition, and temporal and spatial variations of the region (see *Bulletin No. 30*). Among other findings, these studies outlined within the vast region of geomagnetic trapping two belts—the "Van Allen belts"—in which the intensity of the trapped radiation is extremely high.

The data obtained in the NERV experiment will be of particular interest with regard to the interaction of the radiation region with the Earth's atmosphere and magnetic field. Since the NERV flight provided a profile of measurements through

part of the inner Van Allen belt, which begins at an altitude of 700 miles in this geomagnetic latitude, the results of the experiment will be used to help determine which of the various theories on the nature and characteristics of the inner region may best apply.

Results of the NERV experiment also pertain to future manned space flight. Since the radiation is continually changing and fluctuating in character, it is important to map the region in detail in order that adequate, minimum-weight shielding can be designed for manned flight through it. To do this, it is necessary to know the types of particles, their energy spectra, and the fluxes to be encountered.

The stack of 25 nuclear emulsions carried in the recovery vehicle were designed to record the passage of any charged particle with sufficient velocity to penetrate them—5 million electron volts (mev) or more. The particles leave "tracks" in the emulsions, thus producing a permanent record of the number of particles encountered as well as their charge, mass, velocity, and direction of travel in space relative to the emulsion.

The nuclear emulsions are similar to ordinary photographic emulsion, consisting of silver bromide grains embedded in a gelatin, but have a higher percentage of silver bromide and are much thicker. The nuclear emulsions used in the NERV experiment vary in sensitivity and thickness, but most are 600 microns thick (about 1/40 of an inch). Because of the thickness, almost two weeks were required to process these emulsions.

The shield around the emulsions prevented particles having energies of less than 150 mev from entering the emulsions except through the port. After the shield was extended forward, at the designated altitude, the stack was rotated behind the port, by a chronometrically driven motor, for one revolution during the period of exposure. The emulsions were nicked around their peripheries, and the nicks were aligned with the port and with a marked disk on top of the stack. When the stack was rotated, a time-sequence record of entering particles was thus obtained.

Measurement of the angular distribution of particles with respect to the lines of force of the Earth's magnetic field was achieved by the choice of an appropriate direction and angle of launch. The launch azimuth was 193° and the angle was 83° (or nearly vertical). During the rocket's ascent, its spin-axis paralleled the geomagnetic lines of force, making it possible to determine the angular distribution of particles in relation to the spin-axis. Thus, since the time, altitude, spin-rate, and attitude of the launch vehicle are known, a time history of the particles has been permanently recorded: i.e., the investigators can determine the number, distribution, velocity, angles, and directions of travel of the particles at a given position in the radiation region.

Biological Experiment

The three packages of neurospora (mold spores) carried inside the recovery vehicle were unprotected against radiation, and the intensities of radiation encountered were recorded by the emulsions. The spores are being studied for mutations resulting from their exposure to the known radiation field.

World Warning Agency Report
January 1 - June 30, 1960

The following report summarizes solar-terrestrial activity and related decisions of the World Warning Agency (AGIWARN) for the first half of 1960. Other reports in this series appear in earlier *Bulletins;* a review of geomagnetic disturbances and AGIWARN decisions for the IGC-1959 period was included in *Bulletin No. 89.*

The World Warning Agency, supported by the National Science Foundation and operated by the National Bureau of Standards at Fort Belvoir, Virginia, was established as part of the IGY World Days Program (see *Bulletin Nos. 2* and *5*). It continued to function on approximately the same level, with certain procedural modifications, during IGC-1959 (see *Bulletin No. 23*) and through June 1960. After June 30, 1960, when NSF support terminated, NBS assumed responsibility for much of the program.

AGIWARN Report: First Half, 1960

A total of 20 major solar flares (those classified 3 or 3+ in importance by at least one observatory) and 24 geomagnetic disturbances were recorded by AGIWARN during the period January 1-June 30, 1960. However, solar and geomagnetic activity were comparatively mild during the first quarter but became far more severe in the second three-month interval. A geomagnetic storm that began on March 31 was the most severe recorded since July 1959, and was associated with the longest radio disturbance in many years; in addition, the June 1 solar-flare was one of the largest observed in recent years.

First Quarter: AGIWARN recorded 10 geomagnetic disturbances during the first quarter of 1960, the quietest three-month interval from a geomagnetic and radio standpoint since before the IGY. The most significant disturbance was a geomagnetic storm that began on March 15 and reached maximum intensity early the next day, when a K-index of 6 was recorded (the K-index scale of magnetic disturbance ranges from 0, or very quiet, to 9, or extremely disturbed). This was the highest K-index of the year up to that time.

March 16 was also the only day of the quarter when the whole-day radio-quality index (weighted average of four 6-hour indices) was in the disturbed range. Of only seven disturbed 6-hour radio-quality indices during the quarter, five occurred during the March 15–17 storm.

The geomagnetic disturbances of January 5 and 13 began suddenly and are thought to have been associated with observed solar-flare activity. The other eight began gradually and were more typical of the kind of storms to be expected during this period of diminishing sunspot activity.

Second Quarter: During the April 1-June 30 interval, 10 out of a total of 12 geomagnetic disturbances were more severe than any that had occurred in the first three months of the year, and associated radio-propagation conditions were correspondingly much more disturbed. There was a total of 17 days for which the whole-day radio-quality index was in the disturbed range, and the number of 6-hour disturbed periods totaled 67 (March 31 is included in this count because the disturbance beginning on that date lasted through the first three days of April).

About half the geomagnetic disturbances in the second quarter appeared to be associated with solar events of relatively short duration and having well-defined, observable beginnings and endings. Included among these "event"-type disturbances,

however, were some geomagnetic storms that had gradual beginnings, while some storms that commenced suddenly could not be associated with observed solar activity at all. The major storms were all event associated.

The storm beginning on March 31, which was associated with an active solar region, was accompanied by severe and protracted disruption of high-frequency radio communications: for approximately 36 hours, radio quality was defined as useless. Although the storm that began on April 27, the quarter's second most severe disturbance, has not been linked with an observed solar event, sudden resurgences of geomagnetic activity on April 30 are believed to have been related to flare activity on the 28th. The third most important geomagnetic disturbance of the quarter, on May 8–9, was associated with observed flare activity.

A cosmic-ray-intensity increase on May 4 is thought to have been associated with the May 5 magnetic storm. This cosmic-ray increase is the only one for which Advance and World-wide Geophysical Alerts have been issued by AGIWARN (see *Bulletin No. 23*).

Solar and Geophysical Activity and AGIWARN Decisions, January 1-June 30, 1960: The following is a list of major solar flares, geomagnetic disturbances, World-wide Geophysical Alerts, and Special World Intervals (SWI) for the first half of 1960:

Jan	5	0202	Magnetic storm begins
	6	05xx*	Magnetic storm ends
	7	1504	Class 3 flare; S-SWF**
	10	06xx	Magnetic storm begins
	11	1600	Alert issued†
		2040	Class 3 flare; Slow S-SWF**
	12	03xx	Magnetic storm ends
	13	1900	Magnetic storm begins
	14	1600	Alert issued
	15	1352	Class 3 flare; Slow S-SWF
		18xx	Magnetic storm ends
	17	12xx	Magnetic storm begins
	18	1600	Alert issued
		21xx	Magnetic storm ends
	21	00xx	Magnetic storm begins
		1600	Alert issued
	25	00xx	Magnetic storm ends
Feb	5	06xx	Magnetic storm begins
		1600	Alert issued
			SWI starts††
	6	10xx	Magnetic storm ends
			SWI finishes
	13	19xx	Magnetic storm begins
	14	1600	Alert issued
		23xx	Magnetic storm ends
	16	09xx	Magnetic storm begins
		1600	Alert issued
	21	21xx	Magnetic storm ends
	22	1352	Class 3 flare; S-SWF
	26	0700	Class 3 flare
Mar	10	07xx	Magnetic storm begins
	11	22xx	Magnetic storm ends
	15	12xx	Magnetic storm begins
	16	1600	Alert issued
	17	22xx	Magnetic storm ends
	27	0657	Class 3 flare; Slow S-SWF
	29	0705	Class 3 flare; S-SWF
	31	08xx	Severe magnetic storm begins
		1600	Alert issued
			SWI starts
Apr	1	0854	Class 3 flare
		1600	Alert issued; auroras expected
	3	13xx	Severe magnetic storm ends
			SWI finishes
	5	0255	Class 3 flare; Slow S-SWF
	10	22xx	Magnetic storm begins
	12	0130	Class 3 flare
		1600	Alert issued
	13	12xx	Magnetic storm ends
	23	21xx	Magnetic storm begins
	24	1600	Alert issued
	26	11xx	Magnetic storm ends
	27	2000	Severe magnetic storms begins
	28	0130	Class 3 flare; Slow S-SWF
		1600	Alert issued; auroras expected
			SWI starts
	29	0209	Class 3 flare; Slow S-SWF
May	1	10xx	Severe magnetic storm ends
			SWI finishes
	4	1015	Class 3 flare; S-SWF
		1600	Alert issued for cosmic ray increase
	5	20xx	Magnetic storm begins
	6	1404	Class 3+ flare
	7	1600	Alert issued; auroras expected
			SWI starts
	8	00xx	Magnetic storm ends
		0422	Severe magnetic storm begins
		1600	Alert issued; auroras expected
	9	0704	Class 3+ flare
		11xx	Severe magnetic storm ends
			SWI finishes
	11	0438	Magnetic storm begins
		1600	Alert issued
	12	22xx	Magnetic storm ends
	13	0522	Class 3+ flare; S-SWF
	16	12xx	Magnetic storm begins
		1600	Alert issued
	17	14xx	Magnetic storm ends
	23	14xx	Magnetic storm begins
	24	1600	Alert issued
	25	05xx	Magnetic storm ends
	28	2020	Magnetic storm begins

	29	1600	Alert issued
	30	17xx	Magnetic storm ends
	31	16xx	Magnetic storm begins
June	1	0824	Class 3+ flare; Slow S-SWF
		15xx	Magnetic storm ends
	4	0250	Magnetic storm begins
		1600	Alert issued
			SWI starts
	6	18xx	Magnetic storm ends
			SWI finishes
	25	1136	Class 3 flare
		2040	Class 3 flare; S-SWF
	26	2358	Class 3 flare
	27	0145	Magnetic storm begins
		2140	Class 3 flare; Slow S-SWF
		1600	Alert issued
	29	08xx	Magnetic storm ends
		1937	Magnetic storm begins
	30	1600	Alert issued
Jul	2	17xx	Magnetic storm ends

* "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined.

** Symbols for ionospheric effects are defined as follows: S-SWF—sudden short-wave fadeout and gradual recovery; Slow S-SWF—slow short-wave fadeout (taking 5–15 minutes) and gradual recovery.

† No ending times for alerts are issued, as was done during the IGY; this is now left to the discretion of individual observatories.

†† SWI's, when warranted, start at the time the associated Alert is issued; they finish at the end of the day indicated.

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Solar Radiation Satellite

The following material is based on a report by T. A. Chubb, H. Friedman, R. W. Kreplin, W. A. Nichols, A. E. Unzicker, and M. J. Votaw, of the US Naval Research Laboratory. The experiment, of interest to geophysicists and solar physicists, was carried out in a "piggyback" satellite launched with Transit II-A, a Navy vehicle.

The United States Naval Research Laboratory's Solar Radiation Measuring Satellite, or "Sunray," launched from Cape Canaveral, Florida, at 1:54 am EDT on June 22, 1960, is transmitting the first continuous measurements of solar activity in terms of the sun's X-ray and ultraviolet radiations. Sunray was carried into orbit clamped to the Transit II-A navigational satellite, from which it was disconnected by a spring device about 30 minutes after launch and ejected into a separate orbit. The Sunray satellite, designated 1960 Eta 2 (Transit II-A is 1960 Eta 1), is, in fact, an orbiting elementary solar observatory.

Solar ultraviolet and X-ray radiations are responsible for the formation of the ionosphere of the earth. These radiations are variable and produce day-to-day and seasonal changes in ion density and, during solar flares, sudden ionospheric disturbances that seriously disrupt long-range radio communication and navigation systems. When satellites have collected enough data on these radiations, much more will be

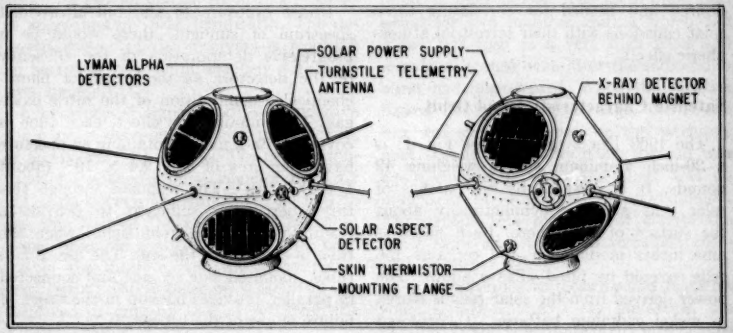

Fig. 1. *Two Views of 1960 Eta 2.* (*Adapted from NRL photographs.*)

known about ionospheric behavior and it may then be possible to improve predictions of the range of short-wave communications.

Much of the most recent knowledge about solar X-ray and ultraviolet radiations has been acquired through rocket-astronomy experiments. The Naval Research Laboratory has been conducting such experiments at intervals since 1949. Two examples of knowledge gained through these solar rocket-astronomy studies are the finding that X-rays streaming from the sun are generated primarily in the sun's corona, and that the sky is covered with still-unexplained blotches of ultraviolet radiation.

Although very significant, information from rocket experiments has been limited by the brevity of rocket observation periods (about six minutes per rocket flight), by the relatively small number of rockets that can be instrumented and flown each year, and by the variability in rocket and instrument behavior from one flight to the next. These limitations do not apply to a solar-satellite-photometry experiment, however, because of the comparatively long and continuous observation period (up to a year or more in the NRL Sunray experiment) made possible with a single instrument package in orbit. Thus, the 1960 Eta 2 experiment is expected to provide, for the first time, a reliable time history of solar radiations and to yield the kind and quantity of data long desired and needed for correlating these solar emissions with their terrestrial atmospheric effects.

Satellite Characteristics and Orbit

The 1960 Eta 2 satellite (see Fig. 1) is a 20-inch aluminum sphere weighing 42 pounds. It is powered by six patches of solar cells arranged symmetrically about the surface of the sphere. Each patch is nine inches in diameter and contains 156 cells covered by fused silica windows. The power derived from the solar cells is stored in nickel cadmium batteries. Telemetered data is radiated on a frequency of 108.000 mc/sec from four 25-inch tubular antennas protruding from the satellite's equator 90° apart. It is tentatively planned to continue the experiment for one year, when the transmitter may be turned off by radio command.

Once every 101.5 minutes, 1960 Eta 2 completes an orbit with a 657-mile apogee and a 382-mile perigee, and inclined 67.5° to the equator. Examination of records obtained during the first three months since the launch indicates that the experiment is working as planned.

Instrumentation and Measurement Techniques

The Lyman-α ionization chambers are cylindrical in shape, 3.4 cm in diameter and 2.4 cm long. Each chamber is fitted with a lithium fluoride window and filled with nitric oxide (NO) at a pressure of 15 mm of mercury (Hg). The detectors have a quantum yield, or photoelectric efficiency, of the order of 30% and are sensitive to wavelengths between 1040A and 1340A; the first is determined by the transparency of the lithium fluoride and the second by the ionization potential of the nitric oxide gas. In this wavelength range, Lyman-α radiation is the predominant solar emission and contributes all but 10% of the ion-chamber response.

Under exposure to the full ultra-violet spectrum of sunlight, there would be a progressive deterioration of the efficiency of the detectors as the result of photochemical decomposition of the nitric oxide gas. To minimize this effect, each tube is covered with a mask containing an aperture having an area of only 9.4×10^{-3} (about 1/10,000) cm^2. The response through this tiny aperture is sufficient to provide a readily measured current signal when the tube is exposed to the sun. The use of two tubes, mounted side by side and connected in parallel, provides backup in the event of failure of one of the tubes.

The X-ray detector is also an ionization

chamber. It contains a beryllium window with a surface density of 0.025 gm/cm^2 and an open area of 2.33 cm^2. The absorbing gas is argon at a pressure of 760 mm Hg. Depth at normal incidence is 2.54 cm.

Maximum efficiency of the X-ray detector, 76%, occurs at 2.8A. The X-ray chamber is mounted on the equator of the satellite behind the gap of a permanent magnet having a field strength of about 3000 gauss. The magnet gap is 3/8 of an inch wide and one inch square in cross-section. The magnet serves as a "broom," preventing the passage of low-energy electrons of the Van Allen radiation belt with nearly 100% effectiveness for energies below 0.5 mev.

Parallel to the Lyman-α detectors is a photocell sensitive to visible light. The photocell signals are used to determine the angle between the satellite's spin axis and the sun. This information is necessary to correct the responses of the ionization chambers with respect to the satellite's position relative to that of the sun.

Telemetry

A 10-channel AM-FM telemetry system using a carrier frequency of 108.00 mc/sec transmits the Lyman-α, X-ray, and solar-aspect data. Radiated power is 30 mw. To receive and de-modulate the solar-radiation data at a ground station requires a receiver of approximately 8-kc bandwidth. The detected output of the receivers is recorded on magnetic tape simultaneously with real-time signals.

A solar aspect signal produces a positive going pulse once each roll of the satellite, or about every 10 seconds. The peak amplitude of the aspect pulse is determined by the angle betwen the sun and a normal to the spin axis of the satellite. A Lyman-α signal produces a negative pulse once each roll of the satellite, and an X-ray signal produces a positive pulse once each roll but displaced in time by 180° of roll from the Lyman-α pulse.

At present, signals from the satellite are being received and recorded by Minitrack stations at Blossom Point, Maryland, Lima, Peru, Santiago, Chile, and Woomera, Australia. Tapes are sent to NRL for data reduction. The duration of reception during any given pass of the satellite depends on its altitude and latitude relative to the ground station. Under the best conditions good signal-to-noise ratio is obtained for as long as 15 minutes and, on the average, telemetry reception is good for 7 or 8 minutes.

Experimental Results

On August 6, 1960, data were received during a pass by 1960 Eta 2 over Blossom Point, Maryland, simultaneously with a Class 1 solar flare that lasted 18 minutes. The flare began just as the satellite came within range of the station, and six minutes of clear signal reception showed the history of development of ultraviolet and X-ray emission in relation to ionospheric behavior and to solar-radio noise.

One minute after the start of the visible flare, short-wave radio signals began to fade; two minutes later, cosmic radio noise began to fade. At this point, the satellite signals clearly showed an increase in the intensity of solar X-rays. One minute later, the sun began to emit a strong radio-noise burst at 2800 mc/sec. The noise burst persisted for two minutes, during which the X-ray flux rose to a very high level and remained intense even after the radio-noise burst had disappeared. When the satellite passed out of reception range, the X-ray flux was still strong, but on the satellite's next transit, two hours later, the sun was again completely calm and there was no indication of abnormal X-ray emission. Throughout this sequence of events the sun's ultraviolet radiation remained completely unchanged.

As it continues to measure and transmit solar Lyman-α and X-ray emissions, the satellite should contribute many new records

of solar activity. Since the value of the experiment would be greatly enhanced by broader telemetry-reception coverage along its orbit, efforts are under way to expand the ground-station network from the original four stations to perhaps ten. By combining and overlapping the observations of a number of stations, it should be possible to obtain the full time history of the X-ray and Lyman-α variations accompanying a wide variety of solar activity in the optical and radio spectra.

Additional Information

The Naval Research Laboratory welcomes participation in this experiment by scientists outside the United States. The information contained above, along with that added below for this purpose, permits any interested scientist to reduce telemetry data from 1960 Eta 2 to X-ray and ultraviolet intensities. At any individual site it should be possible to capture portions of many interesting solar events during the course of several months' observation.

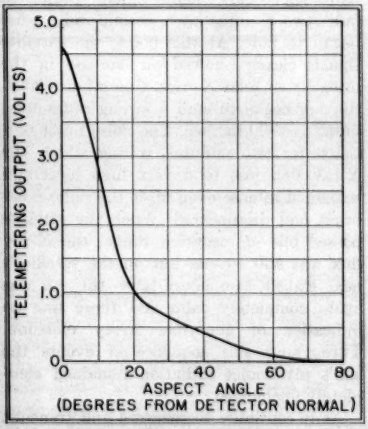

Fig. 2. *Calibration Curve for Solar-Aspect Photocell.*

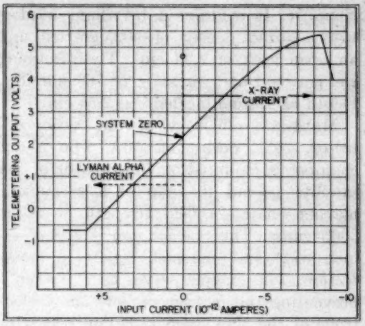

Fig. 3. *Calibration Curve for Lyman-α and X-ray Sensors. Ionization current is shown as a function of telemetered voltage.*

In the telemetry system, two standard IRIG FM sub-carrier oscillators amplitude modulate the RF carrier. The Lyman-α and X-ray data are both on channel 6, center frequency 1700 cycles per second, $\pm$ 7.5% deviation. The aspect data is on channel 5, center frequency 1300 cps, $\pm$ 7.5% deviation.

The magnetic tape on which data are recorded at the ground stations is played back into two FM sub-carrier discriminators, channels 5 and 6, with the output of the discriminators feeding a two-channel paper recorder capable of writing 80 to 100 cps. The real-time signal is also recorded simultaneously.

Channel 5, the aspect channel, has a zero signal level of about 0.3 volts. Two voltage calibration points are transmitted once every eight seconds; the first point represents + 3.9 volts and is followed by a zero volt point, one second later. The relationship between the aspect-pulse voltage at peak amplitude and the solar-aspect angle is not linear. In the range 4.6-1.3 volts, the angle varies from 0° to 20°; from 1.0 to 0.4 volts, the angle varies from 20° to 60° (see Fig. 2).

Channel 6 has a zero signal level of 2.4 $\pm$ 0.1 volts (Fig. 3). As in channel 5, two voltage calibration points are transmitted,

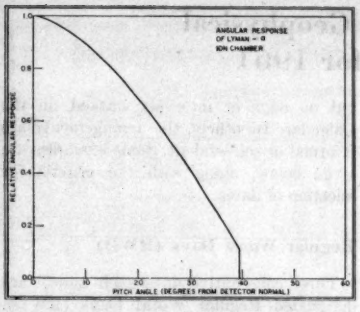

Fig. 4. *Relative-Sensitivity Correction Factor for Lyman-α Detector as a Function of Pitch Angle.*

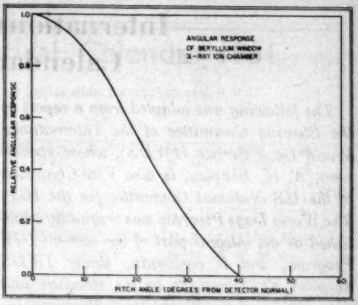

Fig. 5. *Relative-Sensitivity Correction Factor for X-ray Detector as a Function of Pitch Angle.*

but the order is reversed. The zero voltage calibration point occurs first, followed in one second by a + 4.0 volt point.

The peak amplitude of the Lyman-α or X-ray signal is measured on a linear scale in reference to the zero volt and 4-volt calibration points. After converting the peak voltages of the Lyman-α and X-ray pulses to detector current (Fig. 3), a correction is made for the aspect angle (Figs. 4 and 5). The corrected current is then converted to Lyman-α or X-ray intensity in ergs/cm^2/sec. For Lyman-α, the conversion factor is 1.5×10^{12} ergs/cm^2/sec/amp. To convert the X-ray signal to intensity in ergs/cm^2/sec, reference is made to Figure 5 and to the efficiency curve of Figure 6. A true conversion is possible only if the X-ray wave-length distribution is known. Rocket experiments have shown that the X-ray flux declines rapidly as the quantum energy increases. The response of the X-ray detector is, therefore, heavily weighted toward the longer wavelengths and the appropriate factor for most flares would be in the neighborhood of 2.7×10^9 ergs/cm^2/sec/amp.

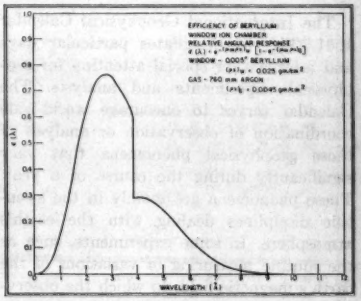

Fig. 6. *Spectral Efficiency of X-ray Ion Chamber.*

International Geophysical Calendar for 1961

The following was adapted from a report by the Steering Committee of the International World Days Service (IWDS), whose spokesman, A. H. Shapley, is also Vice-Chairman of the US National Committee for the IGY. The World Days Program was originally established as an integral part of the over-all IGY Program, and is continuing under IWDS auspices. Other reports on the structure and organization of the World Days Program, including Geophysical Calendars for the IGY and IGC-1959 periods and for 1960, appeared in Bulletin Nos. 2, 5, 23, *and* 29.

The International Geophysical Calendar 1961 (Fig. 8) designates particular days and intervals for special attention for geophysical experiments and analysis. The Calendar serves to encourage world-wide coordination of observation or analysis of those geophysical phenomena that vary significantly during the course of a year. These phenomena are mainly in the scientific disciplines dealing with the earth's atmosphere. In some experiments, such as the routine measuring of variations of the earth's magnetic field, in which the observing and analysis programs at observatories are carried out at a uniform level throughout the year, the Calendar is not needed. However, in many other experiments (rocket experiments, for example), it is not practical or meaningful to carry out the same program on each and every day, and the Calendar can thus provide a useful mechanism for coordination. Experimenters know that their colleagues in other laboratories and in other disciplines also tend to carry out experiments on the days or intervals marked on the Calendar. In this way, results of experiments may be more easily and usefully compared.

In some scientific fields, international scientific organizations have made specific recommendations for programs to be carried out on days or intervals marked on the Calendar. In others, the arrangements are informal or self-evident. Some examples are given below, along with the criteria for selection of dates.

Regular World Days (RWD)

Three consecutive days each month are designated Regular World Days (RWD). RWD always come in the middle, or just after the middle, of the month and include, when possible, the times of equinox and solstice. RWD come in the middle of the week for which they are scheduled—Tuesday, Wednesday, and Thursday— and the three-day groups of RWD are evenly spaced through the year, so far as it is practical. One RWD each month (always Wednesday) is given highest priority, and, whenever possible, RWD include days of solar eclipse and meteor showers.

The RWD are intended for experiments or for observational or analysis programs which, as a practical matter, can be carried out only about 10% of the time and which, for maximum usefulness, should be spaced more-or-less evenly through the year. Further, it is suggested that whenever there are no special reasons for selecting other days, RWD be used for unusual or special experiments. This applies in particular, perhaps, to investigations in atmospheric geophysics, including aspects of cosmic rays, meteorology, airglow, ionosphere, geomagnetism, and aeronomy. Some examples in ionospheric physics are (1) oblique-incidence pulse transmission and reception; (2) absorption measurements by the pulse-reflection technique; (3) extended observing schedules for whistlers and other VLF emissions; (4) vertical-soundings on a faster-than-normal schedule; (5) more-detailed reduction of vertical-sounding ionograms by f-plot, h′-plot, etc.; and (6) hourly reduction

International Geophysical Calendar 1961

Issued November 1960 by the International World Day Service under the auspices of U. R. S. I.

Fig. 8. *Geophysical Calendar for 1961.*

from ionograms of F-region true-height parameters "hc" and "qc."

The highest-priority RWD are for work that can be undertaken for only one day each month. All of the foregoing examples can also be included in the highest-priority category if the rate of three days per month is not necessary or proves to be too heavy. A specific example is the program for 1959 and onwards regarding exchange of copies

of original ionograms in ionospheric vertical-sounding work: the URSI-AGI Committee has recommended that ionograms for the highest-priority RWD each month (and also for one disturbed period each year) be sent to World Data Centers for interchange.

Regular World Intervals (RWI)

Ten consecutive days in each quarter year, selected to include the three RWD of the month in which they are scheduled and the times of the equinox or solstice, are designated Regular World Intervals (RWI). If possible they also include days of solar eclipses and meteor showers, and avoid weekend days and widely observed holidays.

The RWI are intended for experiments that, for practical reasons, cannot be carried on continuously, but for which statistical data on seasonal variations are especially needed. Ionospheric drift and high-atmosphere wind measurements are two examples. Schedules for interchange of sample detailed data in several disciplines have made use of RWI and, in some network observational programs, both RWI and RWD are used to obtain both the variations occurring throughout the year and improved statistical data at the equinoxes and solstices.

World Meteorological Intervals (WMI)

In each quarter, 10 consecutive days displaced one month from the equinoxes and solstices have been designated World Meteorological Intervals (WMI). These intervals are intended to cover the times of marked seasonal change in certain meteorological phenomena, which tend to occur about a month after the equinoxes and solstices. WMI have been chosen through World Meteorological Organization (WMO) and Committee on Space Research (COSPAR) channels as the 16th through the 25th of January, April, July, and October, with January and October designated by COSPAR as the more important ones.

WMI now are primarily periods for carrying out synoptic meteorological rocket programs, with participating stations obtaining atmospheric profiles up to 50 kilometers or more at least once daily during each of the 10-day intervals. WMI have also been used during and since the IGY for balloon-sounding programs involving either special instruments or launchings to unusually high altitudes.

International Rocket Weeks (IRW)

International Rocket Weeks (IRW) for 1961 have been scheduled by COSPAR for (I) February 12–18 and (II) July 16–22. IRW-I will include the total solar eclipse of February 15 and is intended for study of solar-terrestrial effects. IRW-II was selected for study of summer atmospheric structure in the northern hemisphere.

The IRW provide two periods during the year when rocket studies of the atmosphere and of the sun will be on as nearly synoptic a basis as possible at this stage of development of the science and technology concerned. More-detailed recommendations by Working Group 2 of COSPAR, J. Bartels, Chairman, appear in the *COSPAR Information Bulletin*.

Other Special Days

The 1961 Calendar marks the days of solar eclipses—February 15 (total) and August 11 (annular). Some special programs may be expected to be carried out in appropriate parts of the world to study eclipse effects on the earth's atmosphere. It is especially important that the record of solar activity during and near times of eclipses be as full as possible. Many solar-activity observatories therefore issue especially detailed reports of their observations on eclipse days in order to assist in the interpretation of the associated geophysical measurements. Ionospheric stations customarily increase their observing programs on these days even if the magnitude of eclipse at their locations is small.

Also shown on the 1961 Calendar are days when meteor-shower activity is expected to be unusually high. Geophysicists using meteor techniques often enhance their observing programs on these days. Attention is also called to these days because ionization produced by meteors may account for unusual effects in other geophysical experiments.

Special Intervals Not Appearing on 1961 Calendar

The International Geophysical Calendar marks only those dates that can be selected long in advance, either by general agreement or, as in the case of eclipses and meteor showers, by reliable long-term prediction. Periods of great magnetic, auroral, and ionospheric disturbance are also of great geophysical interest, however, and world-wide coordination of observation is clearly desirable. Such special observational intervals are provided for under the auspices of the International World Day Service, in close collaboration with the URSI (International Scientific Radio Union) Central Committee on URSIgrams in the program for the immediate designation of *Geophysical Alerts* and for selection, on a current basis, of *Special World Intervals* (*SWI*).

Arrangements for receipt of such information by telegram or radio broadcast can be made, as may be practical, with one of the solar-geophysical Regional Warning Centers, whose telegraphic addresses are as follows: (Western Hemisphere) AGIWARN WASHINGTON (USA); (Western Pacific) AGI KOKUBUNJI (Japan); (Eurasia) NIZMIR MOSCOW (USSR); (Western Europe) either IONOSPHARE DARMSTADT (GFR) or GENTELABO PARIS (France) or AGI NEDERHORSTDENBERG (Netherlands).

The meteorological telecommunications network coordinated by WMO carries such information once daily soon after 1600 UT. Description of the GEOALERT and SWI plan can be obtained from these centers or from the IWDS Secretary. Many geophysical stations increase their programs or carry on special experiments during disturbed periods; the GEOALERT and SWI program serves to coordinate this on a world-wide basis and is especially useful for stations not near the auroral zones and at which, consequently, the beginning of a major disturbance may not be immediately apparent from local observations.

The IWDS, in close collaboration with the URSI Central Committee on URSIgrams, also promotes arrangements for prompt notification, through the Regional Warning Centers, of major solar-flare events, which have important and sometimes long-lasting geophysical effects.

Calendar Records

A summary record of significant solar and geophysical events is being prepared under IWDS auspices as a Calendar Record for the IGY period and for IGC-1959. If these volumes prove useful, similar Calendar Records may be compiled for 1960 and 1961.

Organization of IWDS and Compilation of 1961 Calendar

The International World Day Service (IWDS) was established in 1958 by ICSU and is administered by URSI, 7 Emile Danco, Brussels 18, Belgium. The IWDS Steering Committee consists of A. H. Shapley (URSI), M. Nicolet (International Union of Geodesy and Geophysics—IUGG), and J. F. Denisse (International Astronomical Union—IAU), with R. Coutrez (URSI) as Secretary. A. H. Shapley serves as spokesman for IWDS and as its correspondent to other ICSU groups such as the International Committee on Geophysics (CIG) and COSPAR. IWDS obtains nominal support from the ICSU Federation of Astronomical and Geophysical Services (FAGS).

The International Geophysical Calendar for 1961 was drawn up by A. H. Shapley and J. V. Lincoln in consultation with URSI, IUGG, and IAU, both directly and through CIG and COSPAR. Recommendations also were made by representatives of WMO and from interested individual scientists. A similar Calendar was issued for 1960 along the lines of the calendars for the IGY and IGC-1959, which were issued under the auspices of the ICSU Special Committee for the International Geophysical Year (CSAGI) and described in the "IGY Instruction Manual for World Days and Communications," *IGY Annals*, vol. VII, Pergamon Press, 1959.

Ionosphere Direct Measurement Satellite

The following report is based on material provided by R. E. Bourdeau, Head, Planetary Ionospheres Branch, National Aeronautics and Space Administration. Responsibilities for the experiments included in the satellite are as follows: J. A. Kane—impedence probe; R. E. Bourdeau, G. P. Serbu, and E. C. Whipple, Jr.—ion traps and Langmuir probe; R. E. Bourdeau and J. L. Donley—electric-field meter; and W. M. Alexander, C. W. McCracken, and Otto Berg—micrometeorite experiments. All of the experimenters are with NASA's Goddard Space Flight Center.

Satellite 1960 Xi (Explorer VIII), designed to provide basic information on the ionosphere by direct measurement, was launched from Cape Canaveral, Florida, at 0523 UT, November 3, 1960, and injected into orbit nine minutes later. The 60-ton, 76-foot Juno II launch vehicle was similar to those used to boost the Pioneer IV space probe (see *Bulletin No. 30*) and to put satellite 1959 Iota (Explorer VII) into orbit (see *Bulletin No. 29*).

The satellite is a project of the National Aeronautics and Space Administration, under the management of NASA's Goddard Space Flight Center. NASA's George C. Marshall Space Flight Center prepared the payload, and designed, developed, and launched the Juno II carrier rocket. The scientific experiments were developed and built by the Goddard Center. The NASA Jet Propulsion Laboratory provided the vehicle's three-stage, high-speed upper assembly.

Satellite Characteristics

The configuration of satellite 1960 Xi, like that of 1959 Iota, is in the form of two truncated cones with their bases attached to a cylindrical equator. The satellite is 30 inches in both height and diameter, and the over-all weight in orbit is approximately 90 pounds. The outer shell is constructed of aluminum. (See Figure 9.)

Four thermistors monitor temperatures at the battery case, within the instrument column, in the vicinity of the micrometeorite photomultiplier tube, and on the inside of the satellite skin at the equator.

Orbit

Initial perigee was 258.44 statute miles, apogee was 1422.65 miles; the satellite's period was 112.75 minutes, and an orbital inclination of 49.98° was obtained.

A perigee as low as possible was desired in order to compare the results of the ionosphere experiments with those from the existing worldwide network of ionosphere virtual-height stations. Data from the virtual-height stations are valid only up to F2 maximum, the altitude of which varies from 200 to 300 miles. An apogee

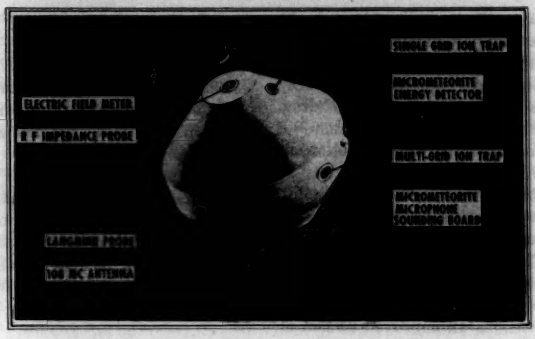

Fig. 9. *Ionosphere Direct Measurement Satellite 1960 Xi (Explorer VIII). (Drawing by NASA.)*

high enough so that the altitude of the base of the exosphere can be determined from the ion mass distribution (ion trap data) was also desired and achieved, and the high orbital inclination permits broad latitude coverage for the ionospheric properties measured. High inclination also permits examination of the micrometeor flux with respect to latitude.

Experimental Objectives

The major objective of 1960 Xi (Explorer VIII) is the study of the temporal and spatial distribution of ionospheric properties, and how they change under such variable conditions as sunlight and shadow. The ionization being investigated consists of particles with low, or thermal, energies, a group that exerts the greatest influence on communications. Results of the measurements may eventually help communications scientists to choose operating frequencies for long-range communications links.

The 1960 Xi ionosphere experiments, unlike those in other NASA-planned ionosphere satellites, do not depend upon radio propagation. Instead, they are all plasma probes that sample the vehicle environment directly, and transmit data over the telemetry link. Plasma probes have two major advantages over propagation methods: (1) they measure a considerably greater number of ionospheric properties and (2) they are much less sensitive to the rapid time variations of ionospheric conditions. On the other hand, the success of the experiments depends upon careful evaluation of the disturbance created in the medium by the presence of the vehicle itself, a factor that does not appreciably affect propagation methods.

The ionospheric properties under study include electron and positive-ion concentrations, electron temperature, and mass distribution of positive ions. Simultaneous measurement of electron and ion concentration will resolve the question of the charge balance, or the neutrality, of the medium. Electron temperature data, when compared with kinetic gas temperatures obtained by other observers, will resolve the important question of thermodynamic equilibrium. If thermodynamic equilibrium is found to exist in the upper atmosphere, measurement of electron temperature might then be the most convenient method of studying temperature distributions in space. Studies of the ion mass distribution will establish the altitude of the base of the exosphere, and will be important to theories of magnetohydrodynamics.

A secondary objective is measurement of the charge accumulation on the satellite surfaces, which can be related to electrical

drag. Consequently, such charge-accumulation measurements are important to studies of the density of the medium, which is now being computed from satellite orbital decay observations that neglect electrical drag. This is particularly important because of the possibility of high satellite potentials in the Van Allen radiation belt.

Other secondary objectives of the satellite are the measurements of the frequency, momenta, and energies of micrometeorite impacts. The momentum range being scanned is considerably larger than that of previous satellites, and the energy measurement experiment is an improved version of one used earlier in a rocket flight. Comparison of the energy and momentum data permits separate determination of the masses and velocities of micrometeorite particles. Since satellite aspect is being measured, the velocity vectors of the particles also can be ascertained. Because of the low perigee, observations are being made of the effects of "sputtering" on the surface of the micrometeorite energy detector. ("Sputtering" is here used to mean erosion of the vehicle surfaces by impingement of all types of particles.)

Description of Experiments

Ionosphere probe 1960 Xi carries seven scientific experiments. The following is a description of the experiments, the equipment used, and the types of measurements made:

Radio-Frequency Impedance Probe: This experiment measures electron concentration by comparing the in-flight capacitance of the sensor, or the amount of electrical charge it will hold, with its free-space value. (The experiment is based on a rocket technique designed and tested by J. E. Jackson.) The sensor, located on the satellite's equator, is a shortened dipole antenna, each half of which is 10 feet long. A measurement of capacitance is made 25 times a second, permitting the experiment to search out ionospheric heterogeneities with dimensions of the order of 300 meters.

Single-Grid Ion Trap: In this experiments positive ion concentrations and mass distributions are measured using techniques very similar to vacuum-tube techniques. The ionosphere provides a near vacuum and also acts as the filament, or ionization source. It is only necessary then to provide a grid and a plate, or collector, to complete the construction of a vacuum tube in space, and with it to study ionization in the immediate vicinity of the satellite.

Multiple-Grid Ion Trap: The objectives and basic principles of this experiment are the same as those of the single-grid ion-trap experiment described above. Comparison of the single- and multiple-grid data will provide an evaluation of the effects upon the ion data of the ion sheath surrounding the vehicle. The accompanying instrumentation is common and time-shared; both experiments were calibrated against an earlier carrier-wave propagation experiment in vertical sounding rockets.

Langmuir Probe: In this experiment, electron temperature is measured by means of two sensors located diametrically opposite each other. Each sensor consists of a collector in the form of a circular plate flush with and insulated from the satellite skin. Both electron and positive-ion currents are measured.

Electric-Field Meter: This experiment determines the distribution of charge that accumulates on the satellite surface by measuring the electric field produced by the ion sheath that forms around the satellite. The sensor, located directly on the spin axis of the satellite, is termed a rotating-shutter-type electric-field meter. It measures electric fields up to 10,000 volts per meter and has a noise equivalent of less than 5 volts per meter.

Micrometeorite Photomultiplier: This experiment measures the light energy emitted as a micrometeorite impinges upon a surface and relates it to the ambient kinetic energy of the particle.

The sensor is a rugged, conventional, "end-type" 7151 C photomultiplier with a one-micron evaporated layer of aluminum on the front surface. A micrometeorite particle penetrating the aluminum coating registers its visible-light energy on the photocathode. The resulting pulse varies in length and amplitude as a function of the micrometeorite's kinetic energy. The maximum sensitivity of the sensor to light pulses is 10^{-3} erg.

Micrometeorite Microphone: In this experiment, the frequency and momentum of micrometeorite impacts are measured. The micrometeorite targets are two "sounding boards" located on the lower cone of the satellite and acoustically insulated from the satellite skin. Attached to each sounding board is a microphone that detects the impulse that occurs when a micrometeorite collides with the sounding board. By pre-flight calibration, the detected impulse can be related to the momentum of the incoming particle.

Telemetry and Power Sources

The telemetry system on satellite 1960 Xi operates continuously so that all data transmission is on the basis of real time. The system is a descendent of that used in the Vanguard program, in which the transmitted signal contains bursts of amplitude modulation separated by periods of no oscillation, or "blanks." The long-term average radiated power output during modulation is 100 milliwatts. At its base, the satellite has a linearly-polarized, quadriloop (clover leaf), 108-mc antenna similar to that used on 1959 Iota. The same antenna functions as the command receiver. For data acquisition, the required pre-detection receiver bandwidth is 50 kc. For this value, a pre-detection signal-to-noise ratio of 14 db at a 1000-mile range has been computed.

Mercury cells are used exclusively as power sources for the 1960 Xi experimentation. All experimental components are operated continuously except the electric-field meter, which is active for two-minute periods only on command. The total power consumption for this experiment is approximately 500 milliwatts. For this capacity and the expected frequency of command exercise, the experiments should be active for at least two months after launch.

Tracking and Data Acquisition

Since the telemetry transmitter operates continuously, a separate tracking transmitter is not included. The NASA Minitrack network provides the major portion of the long-term tracking information. The feasibility of using microlock for additional tracking information was established during prototype testing, and a number of these stations are also being used.

"Planet Earth" Film Series

The National Academy of Sciences has now completed its "Planet Earth" films. Produced under a grant from the Ford Foundation, the series consists of thirteen 16-mm, 27-minute educational films, available in both color and black-and-white, covering the principal fields of geophysical research stressed in the program of the International Geophysical Year.

Origin and Purpose

The film series, the first produced by the Academy, originated in the interest of students, teachers, and the general public in the IGY. The films synthesize man's knowledge of his physical environment, and also delineate newly-developed and powerful tools, such as rockets and satellites, for gathering data on space and the cosmos. Extensive film footage was made for the series in all parts of the world during and after the IGY, thus providing the viewer with the stimulus and interest of field work both at home and in distant places.

Although the inspiration for the program came from the IGY, the films give a rounded picture of man's quest for knowledge in each field, outlining the principal discoveries and ideas and raising questions that still challenge science with regard to the cosmos and the earth itself. The content, in any given field, while utilizing the striking results of the IGY, ranges from early to present-day ideas and experiments, with some projection into the future. Art and iconography are used to present ancient and early notions.

In the production of the films, specialists in each of the thirteen fields were called upon for guidance from all parts of the country and even abroad. Thus, the scientific soundness of the films was ensured. Because many of the ideas in geophysics are abstract, animation is used as needed. Live film coverage ranges from laboratory experiments to field activities. Film crews were sent to many parts of the world to show scientists at work, and how they work, in nature from the tropics to the poles. The legitimate adventure of man's coping with his environment and of scientists' seeking knowledge from nature is often reflected in the field work. Moreover, the planetary character of geophysical problems is revealed by the scenes from other countries and from remote regions like the Antarctic.

Contents

Of the thirteen films, three are devoted to the solid earth: "The Hidden Earth" (seismology), "The Shape of the Earth" (geodesy), and "The Force of Gravity." Three others explore the interface environment between the solid earth and the higher atmosphere: "The Inconstant Air" (weather and climate), "Secrets of the Ice" (glaciology), and "Challenge of the Oceans" (oceanography). Seven films are concerned with the upper atmosphere and space: "Our Nearest Star" (the sun and solar activity), "The Flaming Sky" (aurora), "Magnetic Force" (the earth's magnetic field), "Radio Waves" (including the ionosphere and radio astronomy), "Cosmic Rays," "Research by Rockets," and "Science in Space" (satellite and space-probe research). The following paragraphs briefly describe each film:

The Hidden Earth: The structure of the solid earth is analyzed—from the crust, through the mantle, to the central core. The dynamic quality of the "solid earth" is demonstrated through analysis of earthquakes and volcanoes. Application of seismology to the study of other planets is introduced.

The Shape of the Earth: The study of the size and shape of the earth is presented from ancient times to present concepts derived from data obtained from orbiting

satellites. Present efforts to refine and perfect man's knowledge of the shape of the earth are outlined and the relationship of this effort to future problems of navigation in space is explained. The determination of position and of distances on the earth by astronomical means is examined.

The Force of Gravity: The nature of gravitation is examined from early times to the present. The role of the gravitational field in accounting for the motions of planets is described. Newtonian and Einsteinian theories are explained and contrasted, and gravitational problems of the space age are introduced.

The Inconstant Air: Man's early efforts to measure pressure and temperature afford a basis for understanding the phenomena that make up both weather and climate. Circulation of the atmosphere is portrayed as well as the role of energy from the sun. How meteorological data are collected and how weather forecasts are arrived at are discussed. Theories on climatic changes and how they might come about are described. Current research in the laboratory and using satellite vehicles is presented.

Secrets of the Ice: The role of snow and ice in man's physical environment is explained. Mountain glaciers and ice fields of Greenland and Antarctica are explored with research parties. The relationship between glaciology on the one hand, and oceanography and weather on the other, is explained.

Challenge of the Oceans: The physical aspects of the ocean are examined, including the variety of currents in the ocean, the relationship of the dynamics of the oceans to weather and climate, and the composition of ocean waters. The life cycle in the oceans is sketched. Topography and composition of ocean bottoms is delineated and the structure and content of the sediments are portrayed.

Our Nearest Star: The properties of the sun and the relationship of solar activity to the earth are explained. Such events as sunspots and solar flares, which exert a profound influence on the earth's upper atmosphere, are portrayed. The effect on man's environment of particles and radiations from the sun is analyzed.

The Flaming Sky: The nature of the aurora—the mysterious northern and southern lights—is explored. The development of modern understanding of this phenomenon is traced from the ancient Romans to present beliefs that relate the aurora to emission of charged particles from the sun. The film examines present scientific thinking on what the aurora is, what causes it, and its relationship to other phenomena in man's physical environment, including the earth's magnetic field, radio waves, and solar activity.

Magnetic Force: The nature of the earth's magnetic field is explained, beginning with early speculations. The magnetic field within the earth and that existing in space are described. The film shows how the magnetic field controls the paths of cosmic-ray particles and of charged particles that make up the aurora. The manner in which magnetic force provides man with a better understanding of the earth and the far reaches of the universe is described.

Radio Waves: Both man-made and natural radio waves are discussed, beginning with the discoveries of Heinrich Hertz in the 19th Century. The influence of the ionosphere on radio waves is explained, and the relationship between radio waves, the ionosphere, the earth's magnetic force and solar activity is delineated. The new science of radio astronomy, which seeks to learn more about the universe from radio waves coming to the earth from elsewhere in our solar system and from space beyond it, is described.

Cosmic Rays: A detailed examination is made of present concepts of the origin and

nature of charged particles reaching the earth from outer space. Recent discoveries—using balloons, rockets, and satellites—are presented, and the relationship between cosmic-ray research and nuclear research is outlined.

Research by Rockets: The exploration of the upper atmosphere by instruments carried aloft in rockets is explained. The history of man's attempts to reach out into the higher atmosphere is portrayed and the variety of modern rocket vehicles, including their principles of operation, is shown. Significant discoveries relating to the atmosphere, ionosphere, the earth's magnetic field, cosmic rays, the aurora, and radiations from the sun are examined.

Science in Space: Scientific exploration of space and its contents and the placing of satellites into orbit are explained. Significant discoveries of modern space science are shown, including the Van Allen radiation belts. Radio and optical methods of tracking satellites, the telemetry of data from satellites and space probes to earth, and the analysis of these data are emphasized. The significance of satellites and space probes to man's understanding of the cosmos is stressed.

Production

Hugh Odishaw, of the National Academy of Sciences, acted as Director of the series and Lothar Wolff, of Louis de Rochemont Associates, Inc., served as Producer. The series was produced by the Academy in cooperation with the WGBH Educational Foundation, Cambridge, Massachusetts.

Over two hundred of the nation's leading geophysicists cooperated in the production of the films. To assist in their development, an Advisory Committee on Education (IGY) was established by the President of the Academy. This committee includes Wallace W. Atwood, Jr., Director of the Office of International Relations, National Academy of Sciences; James S. Coles, President, Bowdoin College; Carey Croneis, Provost, Rice Institute; Laurence M. Gould, President, Carleton College; J. Wallace Joyce, Head, Office for Special International Programs, National Science Foundation; Joseph Kaplan, Chairman, US National Committee for the IGY, National Academy of Sciences; John R. Mayor, Director of Education, American Association for the Advancement of Science; Hugh Odishaw, Executive Director, US National Committee for the IGY; Alan H. Shapley, Vice Chairman, US National Committee for the IGY; and Randall M. Whaley, Executive Secretary, Advisory Board on Education, National Academy of Sciences.

In addition to the foregoing, a working group, drawn from the US Office of Education, the National Science Teachers Association, the National Education Association, the National Academy of Sciences, and the National Science Foundation, advised on the production of the film series from the standpoint of stimulating interest in science in general and geophysics in particular.

Distribution

The Academy has concluded an agreement with the McGraw-Hill Book Company, Inc., to provide for distribution of the film series. In accordance with this agreement, McGraw-Hill will distribute the films, either severally or in sets, both in the United States and abroad, to educational and research institutions at the price of $80.00 for black-and-white prints and $150.00 for color prints. The entire series is now available for preview at McGraw-Hill Text-Films, 330 West 42nd Street, New York, New York.